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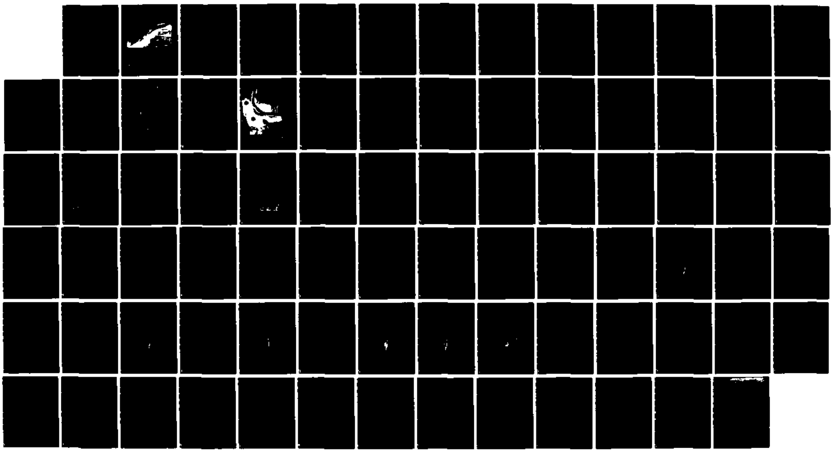

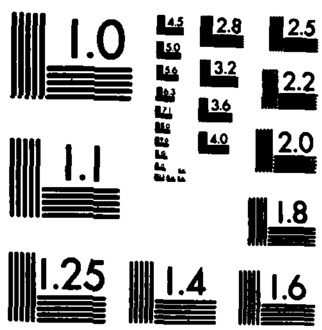

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Feasibility Study for Habitat Development using Dredged Material at Jetty Island, Everett, Washington

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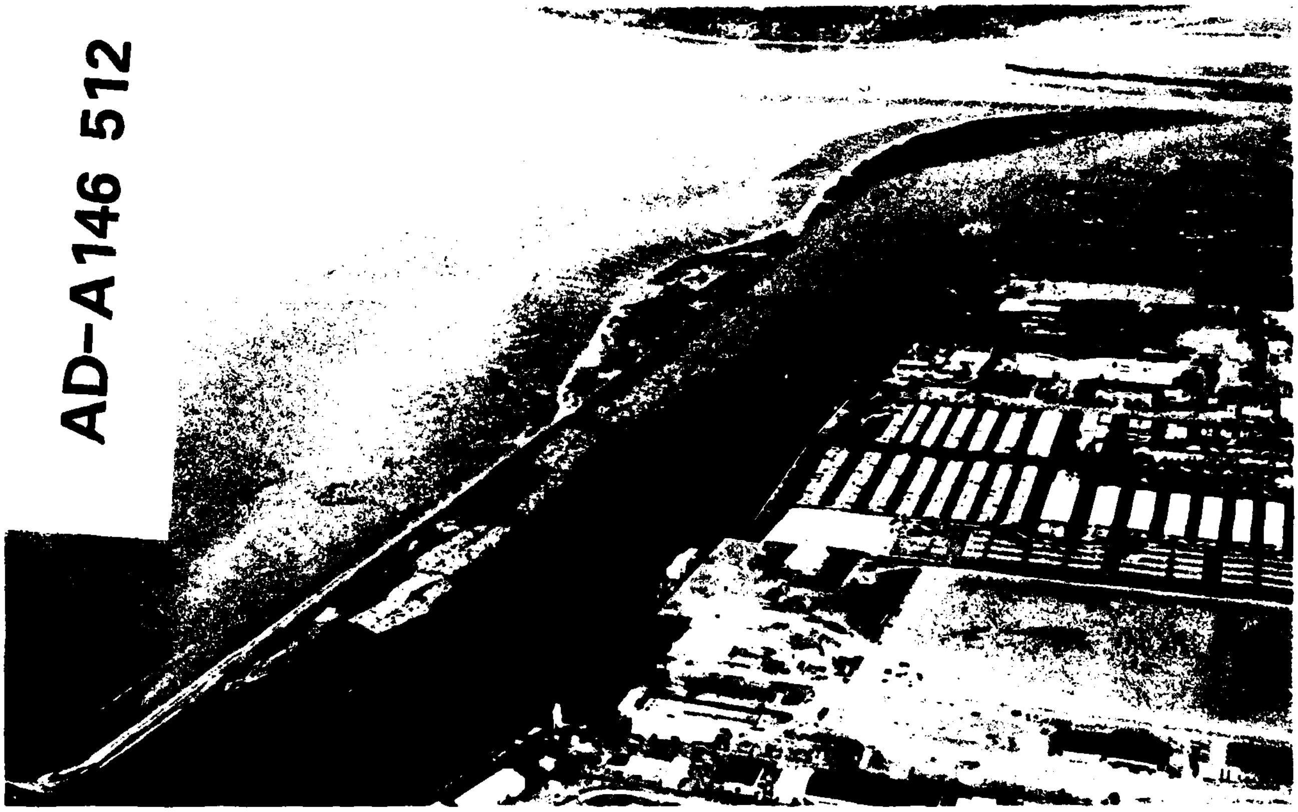

Prepared for:
U.S. Army Corps of Engineers
Seattle District
Seattle , Washington 98124-2255

Prepared by:
Jones & Stokes Associates, Inc.

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FEASIBILITY STUDY FOR HABITAT DEVELOPMENT USING DREDGED MATERIAL AT JETTY ISLAND, EVERETT, WASHINGTON

Prepared for:

U. S. Army Corps of Engineers
Seattle District
P. O. Box C-3755
Seattle, Washington 98124

Contract No. DACW-67-83

Prepared by:

Jones & Stokes Associates, Inc.
1802 136th Place NE
Bellevue, Washington 98005

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The feasibility of developing additional wildlife and fish habitat at Jetty Island, Everett, Washington, using dredged material was explored. Existing literature were reviewed and field surveys undertaken to define environmental conditions at the site and to determine constraints of developing habitat adjacent to the island. Terrestrial plant communities and intertidal habitats were characterized.

> Based on the analysis of field data and literature, the most suitable location for habitat development was found to be on unvegetated mudflats adjacent to the western shore of Jetty Island.

Four alternative concepts (enclosed pond, spit/open lagoon, enclosed lagoon, islands) consisting of seven designs were evaluated. Of those seven designs, four were considered feasible based on such contraints as quantity of material available, tidal and current conditions, stability of substrate, location of dredging sites, and monetary considerations.

The habitat types found to be most suitable for development were salt marsh and beach grassland. The preferred project design is an enclosed lagoon with tidal access via a channel from the protected eastern shore of the island. Approximately 24 acres of marsh community, 6 acres of beach grassland, and 5 acres of sand beach would be created. The project would primarily benefit juvenile fish (salmon, smelt, shiner perch, and Pacific herring), waterfowl, shorebirds, and wading birds.

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PREFACE

In July, 1983, the Seattle District, Corps of Engineers, contracted with Jones & Stokes Associates, Inc., to develop a conceptual plan to develop fish and wildlife habitat at Jetty Island, Everett Harbor, Washington, using material dredged from the Snohomish River navigation channel.

We wish to acknowledge the cooperation of Corps of Engineers staff in providing assistance on this project, Dr. Steven Dice, Chief of Environmental Resources Section; John Malek, Project Coordinator; Dr. Fred Weinmann, Wetlands Ecologist; and support staff who reviewed the document.

Special thanks are due to the Port of Everett for providing access, boat transportation, and background information and to Dr. Klaus Richter for providing information on wildlife use of Jetty Island.

Jonathan Ives of Jones & Stokes Associates, Inc. served as Project Manager; Brian Ross was Lead Biologist; Ron Vanbianchi was responsible for descriptions of botancial resources and vegetation constraints to habitat development; Dr. Harvey Van Veldhuizen and Gregory Ruggerone planned and provided field support for field surveys.

EXECUTIVE SUMMARY

Jetty Island separates Port Gardner (an arm of Puget Sound), Washington, from the lower Snohomish River channel and acts as a breakwater for much of the Port of Everett. The island is wholly man-made, having been created from materials dredged over the years from the lower Snohomish River and deposited on the tideflats west of a dike built to enclose Everett's waterfront. The last such disposal took place in 1975. Today , Jetty Island covers approximately 100 acres above mean higher high water, and extensive mudflats exist to the west. The island provides a variety of upland, wetland, and aquatic habitat types important to the fish and wildlife of the Snohomish River estuary. Its potential as a site for habitat development using dredged material is therefore already established.

On August 12, 1983, Jones & Stokes Associates, Inc. was contracted by the Seattle District, U. S. Army Corps of Engineers to conduct a study of the value and feasibility of using clean material dredged from the Snohomish River channel to further develop specific habitats on and around Jetty Island. The objectives of this study were, by review of the literature and through limited field surveying, to:

- Characterize the habitats of Jetty Island and its associated intertidal areas.
- Identify habitats most appropriate for development on Jetty Island.
- Identify sites physically, biologically and economically suitable to habitat development using dredged material.
- Generally identify species and assemblages most likely to benefit from or be affected by such habitat development.
- Recommend specific conceptual designs for carrying out development of the identified habitats.

It was assumed that 150,000 cubic yards (yd^3) of clean dredged material would be initially available for project development and that this material would be physically and chemically appropriate for intertidal disposal.

Jetty Island today is completely vegetated. This vegetation is composed of five major terrestrial plant communities and two intertidal habitats.

- Scotch Broom Community. Covers ~34 acres (compared to ~30 acres in 1977), primarily on the northern half of the island and is expanding into the beach grassland community.

- Beach Grassland Community. The only beach grassland in the Snohomish River estuary. Cover ~56 acres; this area is dwindling due to invasion by other species. Dune wildrye and bighead sedge predominate.

- Low Salt Marsh Community. Dominated by Lyngby's sedge, this community covers ~1 acre on the southeastern edge of the island. Coverage has not appreciably changed since 1977.

- High Salt Marsh Community. Nine acres of high salt marsh (versus six in 1977) exist in small patches on the island. Several species occur, but 40 percent of the pickleweed dominated marshes of the entire Snohomish River estuary occur on Jetty Island.

- Red Alder Community. The only trees on the island. Less than 1/2 acre coverage on the north end of the island. Little expansion since 1977.

- Marine Algae Community. Sea lettuce, bladder wrack, and *Enteromorpha* are scattered over ~5 acres of the rock jetties and training dike, and in shallow intertidal areas.

- Eelgrass Community. Extensive eelgrass beds exist on the mudflats west of the island. These extend west, beginning ~500-1,000 feet offshore and from south of the island to approximately the bend in the training dike north of the isthmus.

Beach grassland and salt marsh communities are specifically recommended as the habitats most appropriate for development due to their scarcity in the Snohomish River estuary and the fact that they already exist on Jetty Island.

Aquatic life was sampled by nearshore beach seining and along transects on the intertidal mudflats west of the central portion of the island. The organisms collected were typical of other sand/mudflat and eelgrass habitats throughout Puget Sound. However, the species diversity of benthic invertebrates was relatively low. The unvegetated mudflat areas were heavily dominated by burrowing shrimps (*Callianassa* and *Upogebia* sp.) and a small bivalve (*Cryptomya*).

Placement of dredged material is recommended to occur only on unvegetated mudflats west of Jetty Island since such habitats are abundant in the vicinity of Jetty Island and benthic life is relatively sparse. Specifically, it is recommended that development avoid the highly productive eelgrass beds further to

the west. Also, the use of mudflats adjacent to the central area of the island for habitat development is preferable over more northern or southern locations because of island topography, substrate, and proximity to dredging sites. Specific design recommendations are discussed in decreasing order of preference:

- **Design 3A: Enclosed Lagoon, Filled From Uplands.**
  - Fully enclose the bay area with a protective berm of dredged material west of the isthmus in the center of the island.
  - Establish 6 acres of beach grassland at elevations $\geq$ +12-1/2 feet above mean lower low water (MLLW).
  - Reduce ~5 acres of existing uplands to a minimum +8' elevation, using the material to fill the area enclosed by the berm to the same elevation.
  - Open small gaps in the top of the existing training dike to allow tidal inundation to occur from the protected eastern side of the island.
  - Establish 24-acre salt marsh community and approximately 5 acres of sand beach.
- **Design 3B: Enclosed Lagoon, Without Fill From Uplands.**
  - Enclose the same area as Design 3A but do not reduce existing uplands.
  - Place a small channel or culvert across the isthmus so that tidal access is gained from the protected eastern side.
  - Establish beach grassland on the berm, and a ~5 acre fringe of salt marsh around the protected shoreline of the enclosed lagoon.
  - Use material from the next maintenance dredging cycle, 2-3 years later, to finish filling the enclosed area to ~+8 feet MLLW, and establish salt marsh over the resulting ~15 acres.
- **Design 2B: Bowed Spit/Open Lagoon.**
  - Create a spit of dredged material in the same general area as recommended for other designs, leaving a gap at its northern end.
  - Stabilize the point of the spit with some suitable, unconfining material (old tires, rock, etc.).

- Establish ~5 acres of beach grassland above +12-1/2 feet MLLW on the spit.

- Establish ~5 acres of salt marsh around the protected interior shoreline of the open lagoon.

- Use material from the next maintenance dredging cycle, 2-3 years later, to fill most of the enclosed area to +8 feet MLLW or more, and establish salt marsh over the entire ~19 acres.

  [This should be considered only if there is to be no modification of existing uplands. This design is de-emphasized due to the necessity for stabilization materials to control tide and wave erosion at the end of the spit.]

• Design 3C: Enclosed Lagoon/Open Lagoon.

  - Create a spit of dredged material in the same general area as recommended for other designs, leaving a gap at its northern end.

  - Stabilize point of spit.

  - Construct a cross berm joining the spit with Jetty Island, installing a box culvert to allow tidal influx into enclosed lagoon.

  - Establish ~8 acres of beach grassland and 10 acres of salt marsh.

Plant community establishment should take place using only native species. Initial beach grassland development should be done via plantings of dune wildrye, and perhaps beach peavine and silver bursage. Initial salt marsh development should take place via plantings of Lyngby's sedge, pickleweed, seaside arrowgrass, and three-square bulrush between +8 feet and +10 feet MLLW; pickleweed and tufted hairgrass should be planted from +10 feet to +12 feet MLLW. Other appropriate species are expected to establish themselves in these communities by natural invasion.

No other potential habitat development designs are recommended. Similarly, development of other types of habitats (e.g., aquatic including additional eelgrass beds, or upland including other plant communities that would affect beach grassland coverage) are not the most appropriate for Jetty Island nor the most beneficial to the Snohomish River estuary generally and are therefore not recommended.

INTRODUCTION

Access from Puget Sound to the Port of Everett, Washington, via the lower Snohomish River channel is maintained primarily under the authority of the Seattle District, U. S. Army Corps of Engineers. Historically, sediments from maintenance dredging of the lower Snohomish River were deposited on the tide flats just west of a dike separating the river channel from the waters of the Sound. Eventually, the long narrow island named "Jetty Island", was created. Although periodic maintenance dredging of the lower river channel continues to occur, the last addition to Jetty Island took place in 1975.

Jetty Island was created primarily because the site was cost-efficient for disposal of materials dredged from the lower Snohomish River channel. Jetty Island today includes a variety of habitats which are valuable to the Snohomish River estuary as a whole (Shapiro & Associates 1978; Parks 1973). The potential for habitat development on dredged material at the site is therefore already established.

The Seattle District, U. S. Army Corps of Engineers wished to study the value and feasibility of using clean material dredged from the lower river channel to develop and diversify the fish and wildlife habitats around Jetty Island. Specific objectives of this study include:

- Characterization of habitat types and typical species assemblages existing around Jetty Island, including any recent changes.
- Identification of the habitat types most appropriate for development at Jetty Island.
- Identification of the most feasible locations on or around the island for habitat development.
- Development of preliminary conceptual plans for creating specific habitats, including possible physical configurations and plant communities.
- Identification of potential fish and wildlife benefits from such habitat development.
- Recommendation of preferred plans.

Effort toward these objectives included reviewing literature regarding habitat creation with dredged material, recent studies of the Snohomish River estuary, and studies specific to the fish and wildlife of, and habitats on and around, Jetty Island. Field sampling and habitat surveys were also conducted in late summer, 1983.

PROJECT SETTING AND HISTORY

Jetty Island (Figure 1) is located in the outer Snohomish River estuary and separates the lower river channel from Possession Sound. The island is wholly man-made, created from material dredged from the Snohomish River channel, and deposited on the tideflats west of the Port of Everett. Underlying Jetty Island at depths from 3-5 feet is the original substrate, consisting of clean gray sand which originally supported large populations of clams (Parks 1973). This is covered by a layer of fine, highly organic silt of recent origin, likely coinciding with logging, clearing, and diking of the Snohomish River valley over the past 80 years (Parks 1973). Above the layer of silt are the recent sand depositions which make up the bulk of Jetty Island.

Creation of the island began in 1903 when a 12,550 foot dike was constructed on the Snohomish River tide flats to divert the flow of the Snohomish River. This training dike effectively enclosed much of the Port of Everett (Parks 1973). A gap was left in the dike to divert some of the river flow and its sediment load away from the enclosed harbor. (The gap was closed and reopened over the years and remains open today. Over the years, the training dike has been added to so that today it has a total length of 17,300 feet). Material dredged from the river channel shoreward of the dike was deposited immediately west of the dike. Sediment deposition from the Snohomish River and subsequent channel dredging operations increased the size of Jetty Island, but at least as recently as 1944, the island had not been built up to the point that substantial acreages were exposed at high tide (Corps of Engineers Chart E-2-8-57). It reached its present size of approximately 100 acres above mean higher high water (MHHW) with the last dredge material disposal along its shoreline in 1975.

Because of its isolated nature, Jetty Island has been little used by man. Log rafts are moored along its river side, and access for recreation is provided by a boat dock located on the east side of the island. Recreational use of the island appears to be limited mainly to sport fishing, clamming, and picnicking.

Recently, use of the island by the military as an area for practicing helicopter manuvering (including takeoffs, landings, and deployment and retrieval of large concrete blocks) has been observed (Richter pers. comm.).

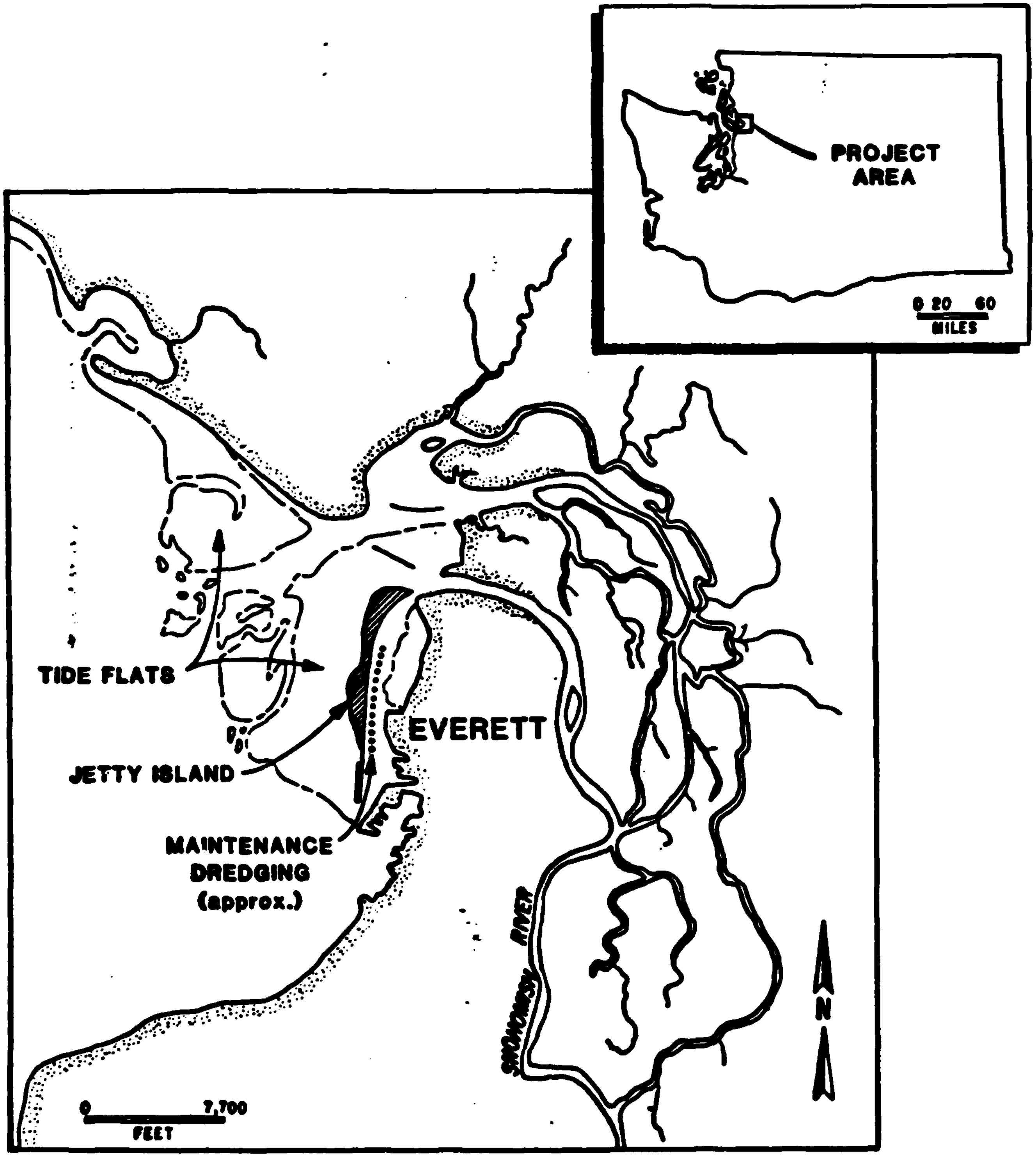


FIGURE 1. THE PROJECT AREA SHOWING THE SNOHOMISH RIVER ESTUARY, JETTY ISLAND AND EVERETT, WA.

EXISTING PHYSICAL & BIOLOGICAL FEATURES OF JETTY ISLAND

Topography and Substrate

Unless otherwise stated, all elevations given are relative to mean lower low water (MLLW) in this report.

Jetty Island runs generally north to south and is low and narrow, with maximum elevations not exceeding ~30 feet above MLLW. High tides of +11.9 feet or higher flood some of the lower elevation areas of the interior of the island. The island substrate is primarily sand, which contains little organic matter (Parks 1973). Little topsoil has built up over the years, with Parks (1973) reporting maximum depths of <2 cm occurring on the north end of the island.

Intertidal sand and mud flats exist on the western side of the island, extending west for over a mile at the lowest tides; on the river side are much narrower mudflats. The substrate of the intertidal areas varies in composition from north to south. Heavier particulates are deposited on the north end of the island, presumably due to current velocity changes (Parks 1973). On the bay side of the island, clean sands predominate at the north end, giving way to silts and muds to the south. Also, going west, particle size decreases across the mudflats. On the river side the pattern is similar, but the overall size of particles deposited is smaller than on the bay side.

Tides, Currents, Waves, and Storms

Limited tide, current, wave, and storm data are available specific to Jetty Island. Tidal conditions are very similar to other areas of Puget Sound. Mean tidal range for Everett Harbor is 7.4 feet, and the extreme range is estimated to be 19 feet (Malek pers. comm.).

Published information on currents in the immediate vicinity of the island is lacking. WDOE (1978) has defined generalized wave height and littoral sediment transport information for the Snohomish River delta, including Jetty Island (Figure 2). The largest waves to which the island is exposed generally originate from the northwest (Port Susan and Saratoga Passage). The maximum fetch from these areas to Jetty Island is approximately 15 nautical miles, and waves heights during storms reach 2-4 feet. Littoral sediment transport is influenced by this exposure. Wave energy is split at the northern and southern "bulges" of the island (Figure 2), resulting in both northward and southward sediment movement at each end of the island. Waves from the northwest tend to be higher at the southern end of the

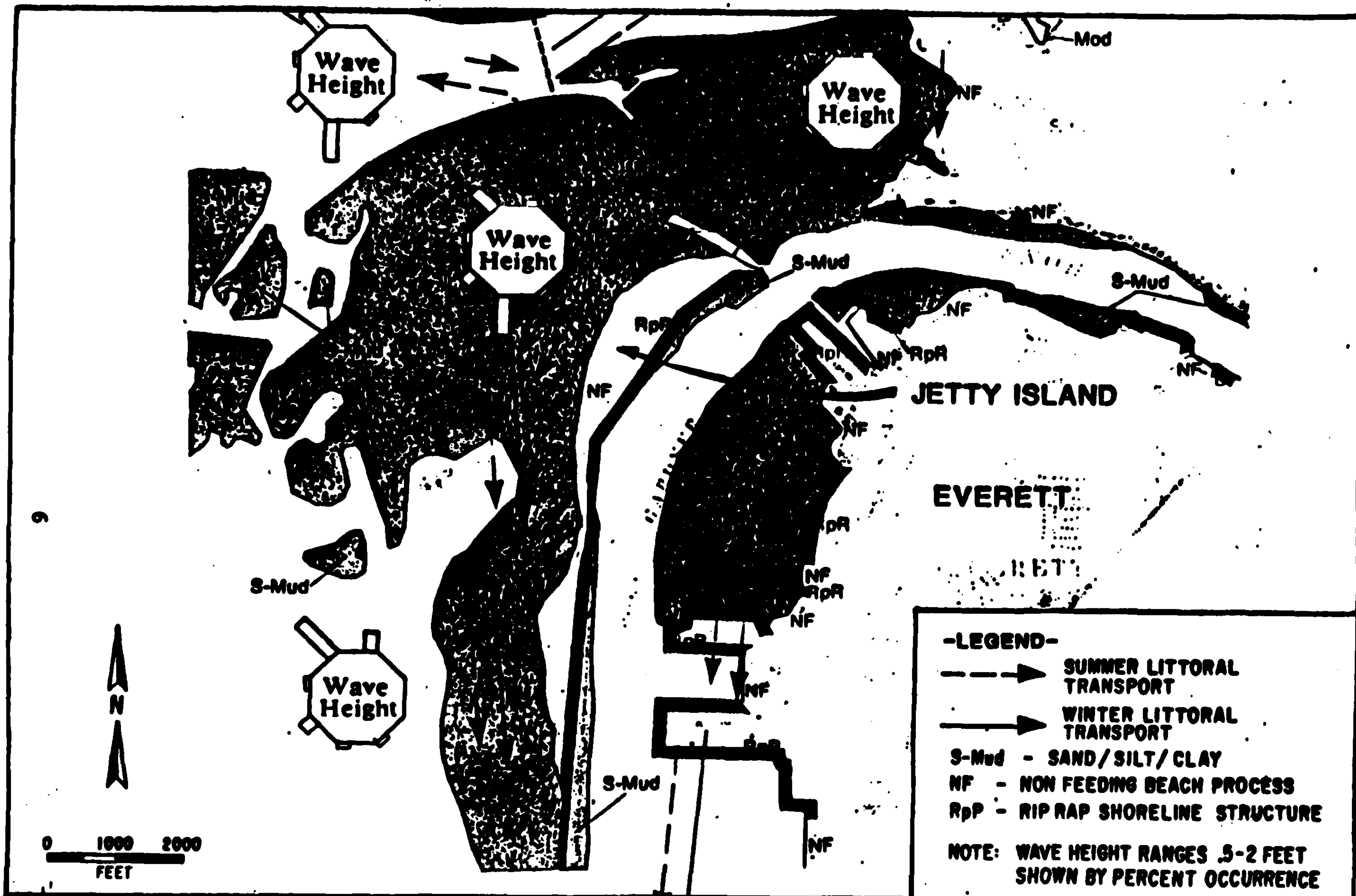


FIGURE 2. GENERALIZED WAVE HEIGHT AND LITTORAL SEDIMENT TRANSPORT AROUND JETTY ISLAND, EVERETT, WA (WDOE 1978)

island, probably due to greater amounts of wave energy being dissipated across the more extensive mudflats off the north end. As the wave energy is split by the southern bulge of Jetty Island, waves moving northward are directed at a sharp angle toward the beach in the area of the center of the island. (In all other areas, the wave energy is directed along the shoreline.) Erosion of the high beach is evident in this area. Except at this location, WDOE (1978) reports Jetty Island to be accreting rather than losing material. However, comparison of 1977 and 1983 aerial photos by Jones & Stokes Associates staff indicates little or no net change in island area over the last 6 years. Shoreline contour also has remained essentially the same. Accretion may be occurring on the intertidal areas. This could be determined by comparison of the last intertidal elevation transects from 1975 (Corps of Engineers Chart E-2-8-173), with new measurements to be made in the near future (Malek pers. comm.). However, one change evident in the aerial photos has been the build-up since 1977 of a low sand bar at the northern end of the island, just south of the gap, extending west from near the shore for approximately one-third mile. This sand bar is not exposed at high tide, but is higher in elevation than the surrounding intertidal area and may serve to deflect a significant portion of the river flow coming through the gap out into the bay and away from the island. If this were the case, it could explain why the 1983 aerial photos show very little increase in the size of the island due to sediment accretion.

Salinity

Salinity has been reported to vary north to south along Jetty Island at any given time (Parks 1973). However, certain factors can greatly influence salinities around the island. Tides significantly affect salinity on a daily basis. At low tide, most of the fresh water leaving the Snohomish River discharges down the dredged river channel along the Everett waterfront, while relatively little is deflected out the gap at the north end of the island. Surface salinities are therefore very low on the river side at times near low tides, while bay side surface salinities are not influenced as greatly by fresh water discharge at these times. As the tide rises, however, this situation reverses. At high tide, a much increased cross-sectional area exists for river water to discharge straight through the gap, rather than being deflected south down the inside of Jetty Island. Hence, at high tide, bay side surface salinities are lower than salinities on the river side. This is especially true nearer the north end of the island. Although bay side salinity is more influenced by river discharge at high tide, the salinity fluctuation is still less than on the river side, where salinity can vary from essentially zero to ~30 parts per thousand (ppt) on one tidal cycle. Another factor which will influence the overall salinities around Jetty Island is the magnitude of flow from the Snohomish River, which fluctuates with the season.

Because the surface salinity can vary greatly, it is necessary to characterize the factors which may influence it at the time any measurements are taken. Without such information, it is extremely difficult to interpret the representativeness of salinity data from this area. The limited measurements of salinity which have been made around Jetty Island are summarized in Table 1, and sampling locations are shown in Figure 3.

Boule and Shea (1978) recorded salinities on the river side at high slack tide at the end of October, 1977. Surface salinities ranged from 17.0-19.0 ppt north to south. Below 3 meters depth, salinities were 25.5 ppt or greater all along the inside of the island. Bay side salinities were measured by Parks (1973). The surface salinities were much lower, with averages ranging from 7.2-15.3 ppt north to south. However, the season and tidal state when the samples were taken were not reported, and the salinities reported were "averaged from about 60 measurements". In the present study, surface salinities were measured at sites on both sides of the island. Some measurements were made near both high and low tides on September 6 & 7, 1983 (Table 1). These late summer measurements are considered to be representative of conditions of low flow for the Snohomish River and therefore of the higher nearshore surface salinities normally encountered around Jetty Island.

Vegetative Cover

The vegetation of Jetty Island was mapped (Figure 4) from aerial photographs taken on September 6, 1983, by the Seattle District, Corps of Engineers. Vegetation changes that have occurred in recent years were recorded by comparing 1983 and 1977 photographs. Also, visits to the island aided interpretation of the aerial photographs, as did comparisons with other studies of Jetty Island vegetation (Parks 1973; Phillips 1977; Shapiro & Associates 1978).

The vegetative cover of Jetty Island has been recorded by several workers during the past decade (Parks 1973; Phillips 1977; Shapiro & Associates 1978). No species currently listed by the Washington Natural Heritage Program (1981, 1982, 1983) as endangered, threatened, or sensitive have been reported.

Parks (1973) describes the vegetation as a "fascinating assemblage", noting the diversity of plant communities and providing species lists based on a sampling scheme laid out along transects. Unfortunately, he did not include sufficient detail in his report to allow quantitative comparisons with other studies.

Parks reported a marked difference between plant occurrence and distribution on the east side of the island travelling from north to south. Specifically, he noted the presence of seaside arrowgrass in the intertidal zone at the north end of the island, and its disappearance and replacement by ditchgrass towards the

Table 1. Salinity Measurements Around Jetty Island, Everett, WA

SITE #a	LOCATION	DATE MEASURED	TIDE STATE	SALINITY (0/00)	COMMENTS	REFERENCES
A	Bay side, near north north end of island	Not reported	Not reported	7.2	Surface measurements. Reported number is "averaged from about 60 samples".	Parks 1973
B	Bay side, directly across from boat dock, lower-central area of island	Not reported	Not reported	11.2	Surface measurements. Reported number is "averaged from about 60 samples".	Parks 1973
C	Bay side, southern tip of island upland	Not reported	Not reported	15.3	Surface measurements. Reported number is "averaged from about 60 samples".	Parks 1973
A	River side, south of southern tip of island upland	10/31/77	High, -37 minutes from slack	19.0	Surface measurement.	Boule & Shea 1978
				26.0	Measurement @ 6 M depth.	
B	River side, mid-channel at turn in dike	10/31/77	High, -32 minutes from slack	18.5	Surface measurement.	Boule & Shea 1978
				26.5	Measurement @ 5 M depth.	
C	River side, mid-channel just south of gap	10/31/77	High, -25 minutes from slack	17.0	Surface measurement.	Boule & Shea 1978
				26.5	Measurement @ 6 M depth.	
1	River side, mid-channel west (upstream) of gap	10/31/77	High, -17 minutes from slack	7.0	Surface measurement.	Boule & Shea 1978
				24.0	Measurement @ 3 M depth.	
1	Bay side, at about transect Station A2, ~1100 feet west of shore, north central area	9/7/83	Low slack	17.0	Surface measurement, in shallow channel on mudflat.	This study (see appendix)
2	Bay side, ~300 feet west of transect Station D3, ~1200 feet from shore, south central area	9/7/83	Low slack	18.4	Surface measurement, offshore in 6" depth water.	This study (see appendix)
3	Bay side, ~30 feet offshore at seine Station 4, across from boat dock, south central area	9/6/83	High, ~1 hour from slack	26.4	Surface measurement.	This study (see appendix)

Table 1. (Continued)

SITE #[a]	LOCATION	DATE MEASURED	TIDE STATE	SALINITY (0/00)	COMMENTS	REFERENCES
4	River side, mid-channel south of marina, near south end of island	9/6/83	Flooding, near high, -2 hours from slack	23.0	Surface measurement. Surface current to the north	This study (see appendix)
		9/7/83	Flooding, near low, +1 hour from slack	0.5	Surface measurement. Surface current to the south	This study (see appendix)
5	River side, mid-channel just north of boat dock, south central area	9/6/83	Flooding, near high, -2 hours from slack	22.7	Surface measurement. Surface current to the north	This study (see appendix)
		9/7/83	Flooding, near low, +1 hour from slack	0.4	Surface measurement. Surface current to the south	This study (see appendix)
6	River side, mid-channel, at turn in dike	9/6/83	Flooding, near high, -2 hours from slack	22.8	Surface measurement. Surface current to the north	This study (see appendix)
		9/7/83	Flooding, near low, +1 hour from slack	0.7	Surface measurement. Surface current to the south	This study (see appendix)
7	At gap, north end of island, on north side of groin	9/7/83	Flooding, near low, +1 1/2 hours from slack	0.6	Surface measurement. Surface current to the west	This study (see appendix)

[a] Site number of the author.
Locations of water quality stations and transects shown in Figure 3.

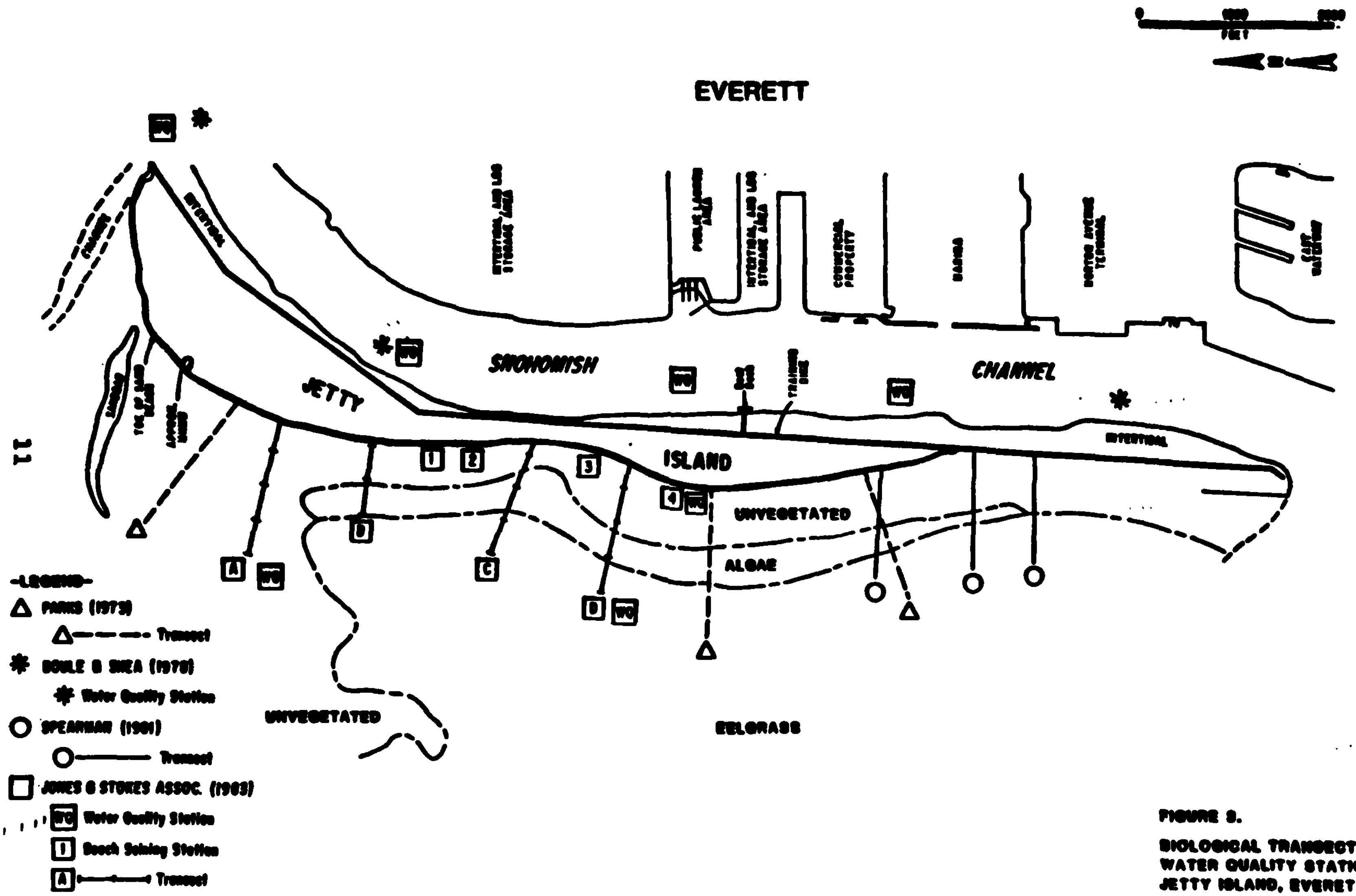
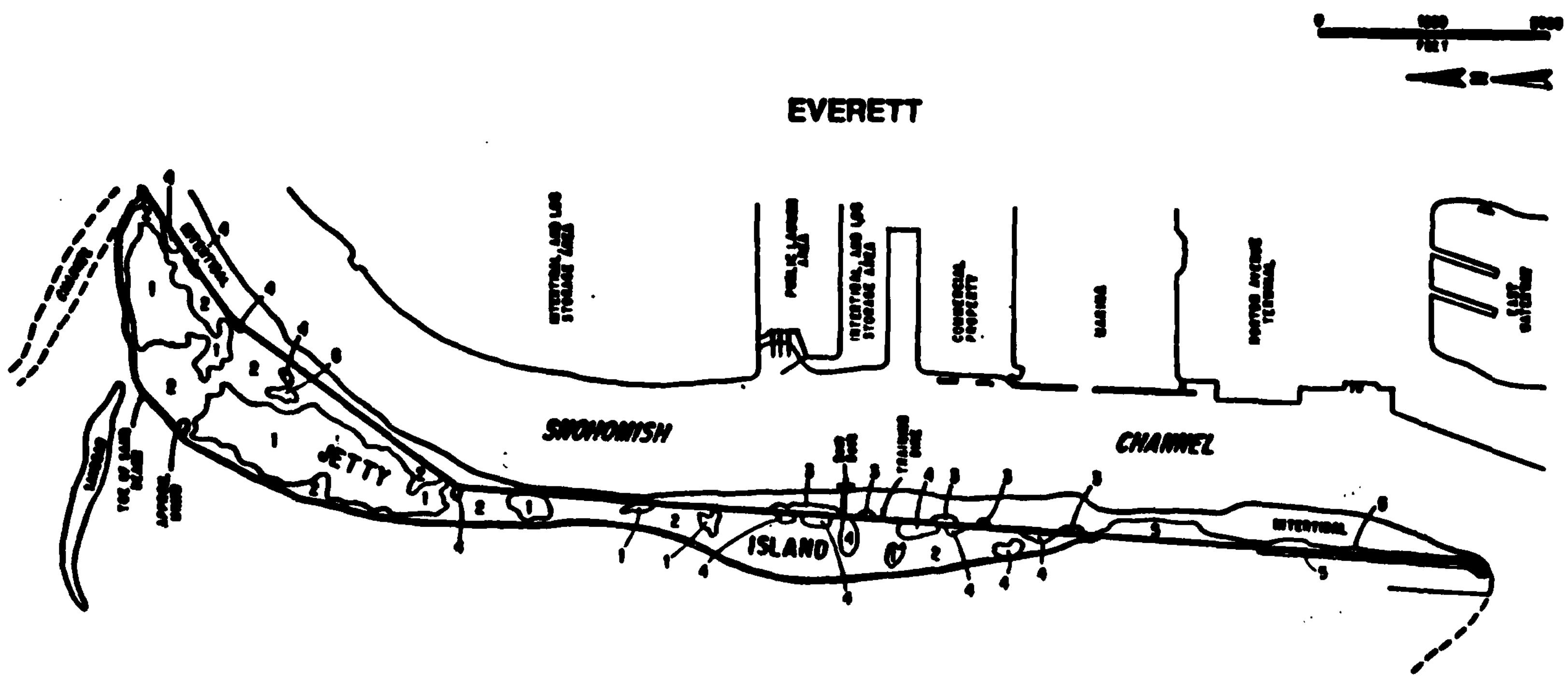


FIGURE 3.
BIOLOGICAL TRANSECTS AND WATER QUALITY STATIONS AT JETTY ISLAND, EVERETT, WA



-LEGEND-

1 = SCOTCH BROOM COMMUNITY
2 = BEACH GRASSLAND COMMUNITY
3 = LOW SALT MARSH COMMUNITY
4 = HIGH SALT MARSH COMMUNITY
5 = MARSH ALGAE COMMUNITY
6 = RED ALDER COMMUNITY

FIGURE 4.

MAJOR VEGETATIVE COMMUNITIES OF JETTY ISLAND, EVERETT, WA (FROM SEPTEMBER, 1983 AERIAL PHOTOS, SEATTLE DISTRICT, US ARMY CORPS OF ENGINEERS)

south end of the island. During this study, seaside arrowgrass was observed occurring with Lyngby's sedge, pickleweed, and several other species in nearly all the low salt marsh areas dotting the intertidal zone on the east side of the island. The "swampy areas" (more properly called marshes, as they lack shrubs or trees) noted by Parks are still discrete communities surrounded by beach grassland and are mapped as "high salt marsh" in Figure 4.

Destruction or modification of the plant cover due to human use of Jetty Island was recorded by Parks and was still evident during the present study. The disturbance is limited to a few established trails and firepits and does not appear to be seriously threatening any of the plant communities at this time. It is not known to what extent recent military use of the island may affect the habitats and wildlife on the island.

In 1978, Burrell created vegetation maps for the entire Snohomish River estuary, including Jetty Island, as part of the Snohomish Estuary Wetlands Study funded by the Seattle District, U. S. Army Corps of Engineers (Shapiro & Associates 1978). At that time, 34 acres of the island were characterized as areas with little or no vegetation. Presently, these areas have sufficient vegetative cover to be included in either the beach grassland or Scotch broom communities. Another change in the vegetation pattern recorded during the present study is the presence of several additional acres of salt marsh communities. This can probably be attributed to three factors:

- expansion of the communities present in 1978,
- colonization of areas that were bare in 1978, and
- previous lumping of several habitat types into one type.

Phillips (1977) qualitatively described the existing Jetty Island vegetation, noting many of the same species that were observed during the present study.

The following community descriptions are based on field investigations performed in September, 1983.

Five terrestrial and two intertidal plant communities were observed and mapped (Figure 4); four are stands dominated by a single species, and the remaining three are plant communities with several co-dominants and composed of many species.

Scotch Broom Community

Approximately 34 acres, primarily on the northern half of Jetty Island, are currently covered by dense stands of Scotch broom (*Cytisus scoparius*). In 1977, 30 acres of Scotch broom existed. Beneath this canopy, many annual and perennial herbaceous species form a sparse understory. These stands appear

to be invading the beach grassland community, particularly the stands of bighead sedge (Carex macrocephala).

Scotch broom is a good sand stabilizer and has been planted along the Oregon coast to help stabilize shifting sand dunes (Wiedemann et al. 1969). Additionally, like all other legumes, Scotch broom increases soil fertility by fixing atmospheric nitrogen and contributing it to the soil as the plants die and decay.

Beach Grassland Community

This plant community presently covers approximately 56 acres on Jetty Island. In 1977, about 57 total acres of beach grassland existed. Area losses due to invasion by the Scotch broom community have therefore been offset by grassland invasion of previously unvegetated upland areas (Parks 1973). Since nearly all upland areas of Jetty Island are now vegetated, it can be expected that total beach grassland acreage will not expand further and may possibly decline in the coming years as other vegetative communities (e.g., Scotch broom and red alder) continue to invade existing grassland.

The beach grassland of Jetty Island is composed of three distinct communities: pure stands of dune wildrye (Elymus mollis); pure stands of bighead sedge; and mixed stands of dune wildrye, beach peavine (Lathyrus japonicus) and many other species characteristic of Puget Sound beach grasslands.

Beach grassland provides nesting, cover, and feeding habitat for a variety of birds and mammals (Albright et al. 1980). A detailed accounting of the species found on Jetty Island is presented in the following sections. The existing acreage on Jetty Island is significant in that it constitutes 100 percent of the total that exists in the Snohomish River estuary (Burrell 1978).

The beach grassland community on Jetty Island presently contains many weedy species that do not characteristically occur in Puget Sound beach grassland communities. This can probably be attributed to the fact that much of the area has recently been colonized, and plants that are generally considered weeds are well suited to that task. In time, and if no further unnatural disturbances occur, the community composition should shift away from having a high percentage of weedy species.

Low Salt Marsh Community

Several patches of low salt marsh exist in the intertidal zone on the east side of Jetty Island. These areas are dominated by Lyngby's sedge (Carex lyngbyei), a common salt marsh plant found throughout Puget Sound, characteristically in the low marsh zone where it colonizes bare mudflat. The total area of Lyngby's sedge is approximately 1 acre and does not appear to have changed appreciably since the 1977 photo survey. These patches also

contain seaside arrowgrass (*Triglochin maritimum*), three-square bulrush (*Scirpus americanus*), seashore saltgrass (*Distichlis spicata*), Jaumea (*Jaumea carnosa*), Lilaeopsis (*Lilaeopsis occidentalis*), low clubrush (*Scirpus cernuus*), ditchgrass (*Ruppia maritima*), and pickleweed (*Salicornia virginica*).

High Salt Marsh Community

Several small patches, currently totaling 9 acres, exist on Jetty Island. In 1977, approximately 6 acres existed, so high salt marsh vegetation appears to be expanding its coverage. These communities are assemblages of many characteristic Puget Sound salt marsh species, including:

- Pickleweed (*Salicornia virginica*)
- Seashore saltgrass (*Distichlis spicata*)
- Orache (*Atriplex patula*)
- Pacific silverweed (*Potentilla pacifica*)
- Seaside plantain (*Plantago maritima*)
- Canadian sandspurry (*Spergularia canadensis*)
- Creeping bentgrass (*Agrostis alba*).

These patches are all situated in low-lying inland areas that are flooded during highest tides (+11.9 feet or higher).

The high salt marsh communities on Jetty Island, although small, are significant in that they include 40 percent of the pickleweed-dominated marshes that exist in the Snohomish River estuary (Shapiro & Associates 1978). Furthermore, these small patches break up the surrounding beach grassland, increasing the overall diversity and wildlife habitat value.

Red Alder Community

Two small patches of red alder (*Alnus rubra*) totalling less than 1/2 acre (as in 1977) exist on the north half of Jetty Island.

Marine Algae Community

Patches of marine algae occur in the shallow intertidal area surrounding Jetty Island, on the rock jetties at the north and south ends of the island, and on the training dike along the island's east side. The intertidal mudflats support sea lettuce (*Ulva lactuca*) and Enteromorpha (*Enteromorpha intestinalis*). The rocky areas are dominated by bladder wrack (*Fucus distichus*).

Eelgrass Community

Extensive eelgrass beds are present on the mudflats west of Jetty Island. The denser portions of the beds begin at ~+1 foot MLLW (~500-1,000 feet offshore) and extend far to the west. The 1977 aerial surveys included infrared photography, which allowed mapping of the submerged eelgrass. More than 1,200 acres of eelgrass were present at that time in the estuary overall; approximately half of this total existed in the vicinity of Jetty Island. The 1983 aerial survey did not include infrared photography, so it was not possible to assess whether the overall acreage of this habitat has significantly changed. The eastern edge of the eelgrass beds, however, appears to be very similar to that mapped in 1977.

Aquatic Life

Estuaries are typically much more productive than associated open water or freshwater wetland areas. Decaying plant life (e.g., from salt marshes and eelgrass beds) provides the primary energy source for major detritus-based food webs, which in turn provide a great deal of net energy to surrounding marine environments. Estuarine primary productivity can exceed 5 g/m^2/day (Albright et al. 1980), compared to 0.5 g/m^2/day for the open ocean (Parks 1973). No similar productivity calculations have been reported for Jetty Island. However, inshore waters of Puget Sound can produce on the order of 3 g/m^2/day (Parks 1973).

Benthos

The benthic life of the intertidal sand/mudflat and eelgrass bed area extending west from Jetty Island has been sampled by Parks (1973), Spearman (1981), and during this study (Figure 3). All of these sampling efforts are discussed below.

Parks sampled the intertidal zone west of Jetty Island in 1973. Three transects were established at low tide (Figure 3), from near the north end to the south end of the island. Parks found very little marine life along the northern transect, whereas along the middle and southern transects marine species were evident. These general patterns were reported as being associated with changes in both salinity and substrate composition from north to south along the island. Species found by Parks are listed in Table 2. Dominant animal species included *Callianassa californiensis* and *Abarenicola claparedii* on the unvegetated mudflats and *Cancer magister* in the eelgrass (*Zostera*) beds. Intertidal plants included *Ulva* and *Enteromorpha*, as well as some *Fucus* and extensive *Zostera* beds further west. The Parks study included only a general list of species found and no site-specific results. Also, few sampling methods were reported (e.g., no seive sizes or sampling sites were given). Hence, the species accounts are descriptive only. Still, the list reported is consistent with species found in

Table 2. Organisms Collected from the Intertidal Sand/Mudflats on the Bay Side of Jetty Island, Everett, WA, from May-October 1973 (Adapted from Parks 1973) (See Figure 3 for Transect Locations)

PHYLUM NEMERTEA
- _Emplectonema burgerri_
- _Paranemertes peregrina_

PHYLUM MOLLUSCA
- Class Pelecypoda
  - _Macoma inquinata_
  - _Macoma inconspicua_
  - _Macoma nasuta_
  - _Transenella tantilla_
  - _Gemma gemma_
  - _Mya aranaria_
  - _Mytilus edulis_
- Class Gastropoda (snails)
  - _Littorina scutulata_
  - _Littorina sitkana_

PHYLUM ANNELIDA
- Class Polychaeta (segmented worms)
  - _Lumbrinereis zonata_
  - _Nereis procera_
  - _Nephtys sp._
  - _Abaranicola claparedii vagabunda_
  - _Clymenella rubrocincta_
  - _Telepsavis costarum_
  - _Polydora socialis_

PHYLUM ARTHROPODA
- Class Crustacea
  - _Synidotea angulata_
  - _Idothea wosnosenskii_
  - _Ione cornuta_ (parasitic on _Callianassa_)
  - _Anisogammarus sp._
  - _Gammarus sp._
  - _Caprella sp._ (attached to _Zostera_)
  - _Balanus glandula_
  - _Callianassa californiensis_
  - _Pagarus sp._ (inhabiting _Littorina_ shells)
  - _Cancer magister_
  - _Hemigrapsus nudus_
  - _Hemigrapsus oregonensis_

other typical sand/mudflat habitats around Puget Sound (Kozloff 1976).

Spearman (1981) sampled along three transects at the south end of Jetty Island (Figure 3). More specific sampling information was given, but most organisms were identified only to class. Table 3 lists the smaller organisms (.064 mm sieve) found in Spearman's study. In addition, Callianassa, Abarenicola, and Lumbrineris sp. were reportedly common. The organisms reported were at least consistent to class with those found by Parks (1973), but no specific comparison with Parks' southern transect, for instance, can be made since Parks' data were not broken down by sampling location. Therefore, it is not possible to determine whether any change in species diversity, abundance, or distribution had occured in the 8 years between the two studies. Spearman's findings, like Parks', also appear consistent with other sand/mudflat habitats in Puget Sound.

Additional intertidal sampling was conducted by Jones & Stokes Associates staff during the present study. Four transects were established in the central area of Jetty Island (Figure 3), and the benthic infauna were sampled at low tide (-1.6 feet MLLW) at three locations along each transect. Table 4 summarizes the species found during sampling, and more detailed descriptions of methods and observations are given in the Appendix.

The intertidal mudflats were dominated by a few species, including burrowing shrimps (Callianassa californiensis and Upogebia pugettensis), small bivalves (primarily Cryptomya californica), and polychaetes. Other bivalves and amphipod species were also relatively common. With the exception of the burrowing shrimps and the small bivalves, however, the overall abundance (no formal biomass estimates were made) of benthic infauna was surprisingly low. The mudflat areas sampled were generally so dominated by the burrowing shrimps as to give the impression that larval/juvenile recruitment by other species may be limited by predation from these shrimps. Other factors that could explain this dominance include salinity tolerance, substrate or elevation preferences, etc.

Of the relatively common species, Cryptomya was more abundant in the southern transects. Other species were either generally distributed or were too rarely collected to determine any distribution trends. Callianassa or Upogebia burrows surface burrow density were similar in abundance between transects and from east to west along a transect (50-80 burrow openings/square meter).

Overall, the species found were similar to those indentified by Parks (1973) and Spearman (1981), but none of the distributional changes reported by Parks (1973) were obvious. This may be because our transects were relatively close together in the central part of the island. Very little overlap has occurred among the three studies relative to the areas sampled. Since sampling methods and precision of identification varied, it

Table 3. Number of Organisms[a] Per 100 ml Sediment Sample Collected from the Intertidal Sand/Mudflats on South Jetty Island, Everett, WA, in April, 1981 (From Spearman 1981) (See Figure 3 for Location of Sample Sites)

INVERTEBRATES COLLECTED	STATION NUMBER[b] AND TIDAL ELEVATION (FROM MLLW) A-270 +9'	A-407 +7.5'	A-1070 +4'	B-300 +6.5'	B-600 +5.5'	B-900 +3.5'	C-300 +5.5'	C-600 +4.5'	C-848 +3.0'
Nemertea	12								
Nematoda	400	640	588	252	180	204	196	352	200
Polychaeta (spionid)	4		8		44		12	24	4
Oligochaeta		16	104			8		8	
Pelecypoda		4			4		4	12	16
Copepoda (Harpacticoid)	116	180	80	104	216	324	222	300	192
Cumacea	2						8		4
Amphipoda	4								
Tanaidacea								4	
Nauplius larvae					8				

a Smaller organisms retained on a .064 mm screen. Larger specimens noted at the site include the ghost shrimp, Callianassa californiensis, the lugworm Abarenicola sp., and polychaetes of the genus Lumbrineris. Ghost shrimp holes were counted at randomly selected stations. Shrimp averaged 50-70 per square meter at elevations +3.0-4.5 feet MLLW, down to 5-15 at elevation +9.0 feet.

b Station name indicates transect and distance (in feet) from shoreline.

Table 4. Organisms Collected by Jones & Stokes Associates, Inc. from the Intertidal Sand/Mudflats on the Bay Side of Jetty Island, Everett, WA, September 6, 1983 (See Figure 3 for Location of Sample Sites) (Numbers Indicate Individuals/0.25m², Except Species with an Asterisk, Where Numbers Indicate Individuals/L in Core Samples)

	Sample Site and Approximate Elevation (from MLLW)											
	A1 ±3	A2 ±0.5	A3 ±1	B1 ±1.5	B2 ±1.5	B3 ±0.5	C1 ±5.5	C2 ±1	C3 ±0	D1 ±6	D2 ±1.5	D3 ±0
PHYLUM NEMERTEA												
Paranemertes peregrina	1						1					
Miscellaneous Nemerteans	6		2		1				1			
PHYLUM MOLLUSCA												
Class Bivalvia												
Clinocardium nuttalii	1					2			2			
Cryptomya californica	3	3	2	10	24	19		36	22	9	19	23
Macoma (*balthica* or *inconspicua*?)	1	1	3				2		1			
Macoma nasuta						1						
Macoma secta		2	1				4					1
Mya arenaria	2	1			1		4		1			
Mya truncata					2							
PHYLUM ANNELIDA												
Class Polychaeta												
Abarenicola pacifica				1								
**Glycera* sp.			1		27	4			37			
Lepidonotus squamatus						1						
Nephtys sp.								4	2			1
Nereis sp.		2	2									
**Paleanotus bellis*										1		
*Miscellaneous Polychaetes	2	1	4		1		1	Many	7	1	Many	2
PHYLUM ARTHROPODA												
Class Crustacea												
Callianassa californiensis						1	1				1	
Cancer magister									1			1
*Miscellaneous Copepods								2				
**Corophium baconi*	3	2				7		13	1			2
*[illegible] *lagunae*								4			3	
**Eohaustorius* sp.										3	1	
*Miscellaneous Gammarid Amphipods							1		1	3		
**Phyllodurus abdominalis* (♂)			1									
Upogebia pugettensis		6	2		4				1			
Total Number of Burrows/m²	70	78	69	61	52	33	64	115	48	67	92	6

Collected, but not in transect samples:

Betaeus harrimani (A Crangonid shrimp)									1			
Clevelandia ios (Arrow goby)											1	

is probably not useful to try to compare these studies in other than the most general terms. Ideally, more sampling should be done on all sides of Jetty Island to characterize habitat use throughout the year. For the time being, the sampling undertaken in this study is sufficient to characterize the intertidal areas west of the central portions of the island only. If dredged material were to be placed in any other area, that area would require further biological characterization.

Fishes

The Snohomish River estuary has been designated an Area of Major Biological Significance (AMBS) for American shad (*Alosa sipidissima*) and English sole (*Parophrys vetulus*) (WDOE 1981). Young shad utilize the Snohomish River estuary as a spring nursery ground. This species is probably expanding its range. The shallow, soft-bottomed areas of Port Gardner are also important spring and winter nursery grounds for English sole.

In general, the aquatic habitat types found around Jetty Island are important to a variety of fishes. Cottids (including the staghorn sculpin collected during this study), flatfish species, and Gobiids (including the arrow goby collected during this study) are often common over sand/mudflat areas. Eelgrass beds are particularly important and are utilized by many local fishes, including those already mentioned as well as herring and salmonids.

During this study, beach seining was performed near high tide on September 6, 1983, within ~100 feet of shore at four sites (Figure 3). Species collected are given in Table 5. Very few fish were caught, shiner perch and juvenile surf smelt predominating. That few fishes were caught does not indicate lack of use of the area. The sand/mudflat area is so wide that, especially after relatively low tides, fishes which normally migrate to higher elevations at high tide may not have had sufficient time to reach the areas sampled (those nearest to shore) at the time of sampling. If seining had been done as the tide was beginning to recede, instead of when not quite fully high, different usage by fishes might have been indicated.

Aquatic Mammals

Harbor seals (*Phoca vitulina*), California sea lions (*Zalophus californicus*), Dalls' porpoise (*Phocinoides dalli*), and possibly the Killer whale (*Orcinus orca*) are marine mammals that can be expected to be observed in the vicinity of Jetty Island.

Pinnipeds have been observed hauled-out on Jetty Island in the past. Harbor seals, especially, tend to haul-out on sand or mud bars at upper intertidal elevations where slopes are fairly gentle (Gentry pers. comm.), though they may also utilize man-made structures and rocky spits or groins (Gentry pers. comm.). California sea lions, on the other hand, are basically undistinguishing in their choice of a haul-out location (Gentry

Table 5. Fishes Collected by Jones & Stokes Associates, Inc. Staff by Beach Seine at High Tide, Within 100 Feet of the Western Shore of Jetty Island, Everett, WA, on September 6, 1983 (See Figure 3 for Sample Site Locations and Appendix for Description of Methods)

SPECIES	SAMPLE SITE 1	2	3	4
Shiner perch (*Cymatogaster aggregata*)	18	13	11	2
Staghorn sculpin (*Leptocottus armatus*)	1	1	1	
Pacific herring (Juveniles) (*Clupea harangus*)		7		
Surf smelt (Juveniles to 100 mm) (*Hypomesus pretiosus*)		4		
Surf smelt (Juveniles to 50 mm) (*H. pretiosus*)		Many		
Chinook salmon (smolt) (*Oncorhynchus tshawytscha*)		1		

pers. comm.). Jetty Island already has appropriate haul-out areas, and indeed harbor seals and California sea lions have been observed using them (Spearman 1981). It is possible that development of more areas which would be attractive as haul-out locations could increase the use of Jetty Island by these mammals.

The harbor seal was listed by WDOE (1976) as a species to which the Snohomish River delta was considered "critical"; but this has been re-evaluated for the WDOE (1981) AMBS study, and the delta is no longer considered as an area of outstanding significance to this mammal.

Snohomish River marsh areas are an AMBS for the river otter (Lutra canadensis) (WDOE 1981).

Avifauna

Due to the varied brush/grassland habitats and relative isolation from human activity, Jetty Island is important to a variety of bird species for loafing, feeding, breeding and nesting. Table 6 summarizes bird use typically found in habitats found in the Jetty Island area.

Jetty Island hosts the only known breeding colony of Arctic tern (Sterna paradisaea) in the contiguous western United States (Manuwal et al. 1979; Paulson pers. comm.; Richter pers. comm.). This species prefers open sand areas for breeding. Peters et al. (1978) identified Arctic terns on Jetty Island as common terns (Sterna hirundo). Although common terns do utilize the island, it is now recognized that they are not known to nest there. Common tern breeding colonies mapped by Peters et al. (1978) actually represent Arctic tern breeding sites. Two Arctic tern nesting areas were recorded in 1977 by those authors, one near the bend in the training dike just north of the island's isthmus and one near the northernmost tip of the island. No nests were observed during surveys in May, 1984 (Richter pers. comm.). Few suitable nesting areas exist on the southern end of the island, but the potential for Arctic tern breeding on the north end is expected to exist for several years (Richter pers. comm.).

Several other bird species utilize the island for breeding. Canada geese (Branta canadensis) nesting has been increasing on Jetty Island recently (Richter pers. comm.). Glaucous-winged gulls (Larus glacescens) and mallard ducks (Anas platyrhynchos), as well as swallows, sparrows, and blackbirds, all nest there (Parks 1973; Spearman 1981).

A variety of birds use the area for feeding and/or loafing. As many as 30 species of waterfowl can be expected to be observed in the vicinity. The Snohomish River estuary, generally, is considered an AMBS for mallard ducks (wintering area for 5,000+ birds) and American wigeon (Anas americana) (wintering and stopover area for 10,000+ birds (Van Wormer 1979 pers. comm. in

Table 6. Salt Marsh Wildlife (From Albright et al. 1980)

SPECIES	MARSH / SLOUGHS	ADJACENT TIDEFLATS (Exposed at low tide)	ADJACENT NEARSHORE (Submerged Tideflats)
BIRDS			
Common Loon			X
Red-throated Loon	X		X
Red-necked Grebe			X
Horned Grebe			X
Eared Grebe			X
Western Grebe			X
Pied-billed Grebe			X
Double-crested Cormorant	X		X
Great Blue Heron	X	X	X
Green Heron	X		
Great Egret	X	X	X
Whistling Swan	X	X	X
Trumpeter Swan	X	X	X
Canada Goose	X		
Brant		X	X
Snow Goose	X	X	X
Mallard	X	X	X
Gadwall	X		
Pintail	X	X	X
Green-winged Teal	X	X	X
Cinnamon Teal	X		
European Wigeon	X	X	X
American Wigeon	X	X	X
Northern Shoveler	X		
Canvasback	X		X
Greater Scaup	X		X
Lesser Scaup	X		X
Common Goldeneye	X		X
Barrow's Goldeneye			X
Bufflehead	X		X
White-winged Scoter			X
Surf Scoter			X
Black Scoter			X
Ruddy Duck	X		X
Hooded Merganser	X		X
Common Merganser	X		X
Red-breasted Merganser			X
Turkey Vulture	X	X	
Red-tailed Hawk	X		
Rough-legged Hawk	X		
Bald Eagle	X	X	X
Marsh Hawk	X		
Osprey	X		X
Merlin	X	X	
American Kestrel	X		
Virginia Rail	X		

Table 6. (Continued)

	MARSH / SLOUGHS	ADJACENT TIDEFLATS (Exposed at low tide)	ADJACENT NEARSHORE (Submerged tideflats)
Sora	X		
American Coot	X	X	X
Semi-palmated Plover	X	X	
Killdeer	X	X	
Black-bellied Plover	X	X	
Common Snipe	X		
Whimbrel	X	X	
Spotted Sandpiper	X		
Greater Yellowlegs	X	X	
Lesser Yellowlegs	X	X	
Willet	X	X	
Sanderling	X	X	
Western Sandpiper	X	X	
Least Sandpiper	X	X	
Pectoral Sandpiper	X		
Dunlin	X	X	
Dowitcher sp.	X	X	
Glaucous-winged Gull	X	X	X
Western Gull	X	X	X
Herring Gull	X	X	X

Table 6. (Continued)

SPECIES	MARSH / SLOUGHS	ADJACENT TIDEFLATS (Exposed at low tide)	ADJACENT NEARSHORE (Submerged tideflats)
California Gull	X	X	X
Ring-billed Gull	X	X	X
Mew Gull	X	X	X
Bonaparte's Gull	X	X	X
Heermann's Gull	X		X
Common Tern	X		X
Mourning Dove	X		
Barn Owl	X		
Short-eared Owl	X		
Belted Kingfisher	X		X
Common Flicker	X		
Violet-green Swallow	X	X	X
Tree Swallow	X	X	X
Rough-winged Swallow	X	X	X
Barn Swallow	X	X	X
Cliff Swallow	X	X	X
Purple Martin	X	X	X
Common Raven	X	X	
Common Crow	X	X	
Dipper	X		
House Wren	X		
American Robin	X		
Western Bluebird	X		
Water Pipit	X	X	
Northern Shrike	X		
Loggerhead Shrike	X		
Starling	X		
Western Meadowlark	X		
Red-winged Blackbird	X		
Brewer's Blackbird	X		
American Goldfinch	X		
Savannah Sparrow	X		
Vesper Sparrow	X		
White-crowned Sparrow	X		
Song Sparrow	X	X	
<u>MAMMALS</u>			
Harbor Seal (<u>Phoca vitulina</u>)	X	X	X
River Otter (<u>Lutra canadensis</u>)	X	X	X
Townsend's vole (<u>Microtus townsendii</u>)	X		
Deer Mouse (<u>Peromyscus maniculatus</u>)	X		
Shrews (<u>Sorex</u> spp.)	X		
<u>REPTILES & AMPHIBIANS</u>			
Red-legged frog (<u>Rana aurora</u>)	X		
Garter snake (<u>Thamnophis</u> spp.)	X		
Rough-skinned newt (<u>Taricha granulosa</u>)	X		

WDOE 1981). Additionally, black brant (*Branta nigricans*) have been observed feeding in eelgrass flats (Richter pers. comm.). The extensive mudflats and narrow sandy beaches on the west side of the island are utilized by western sandpipers (*Calidris mauri*), dunlins (*Calidris alpina*), black-bellied plover (*Pluvialis squatarola*), and other shorebirds. Red-tailed hawks (*Buteo jamaicensis*), marsh hawks (*Circus cyaneus*) (observed during the present study), and nighthawk (*Chordeiles minor*) (Parks 1973) hunt and possibly nest on Jetty Island. Great blue heron (*Ardea herodias*) heavily utilize the extensive tidal flats west of the island for feeding. Short-eared owls (*Asio flammeus*) and wrens have also been observed on Jetty Island.

As plant succession continues and the island's habitat composition changes (at first with the loss of open-sand uplands, toward the continued expansion of brushland over beach grasslands, and presumably to eventual expansion of red alder areas), bird and other terrestrial wildlife use can be expected to change. As an example, Richter (pers. comm.) has noted an apparent downward trend in the densities of nests of glaucous-winged gulls since 1978. Also, he has noted that the gull breeding colonies are migrating northward. However, species utilization of the intertidal feeding areas will likely remain similar in the future to that which exists at present. Those species of shorebirds and wading birds which feed across tidal flats should continue to do so west of Jetty Island.

Terrestrial Mammals

Because of its isolation, Jetty Island is apparently utilized by few terrestrial mammal species. Parks (1973) trapped mice and observed rats on the island and speculated that other small mammals, such as shrews, may be present. During the present study, fresh dog tracks were observed over the intertidal zone at low tide at a time when no other humans were observed on the island. Therefore, it is possible that some dogs have become stranded or are existing feral on the island. No other mammals are known to be established on Jetty Island at this time.

HABITAT CREATION USING DREDGED MATERIALS

Overview

Habitat creation is the consequence of every dredged material disposal operation not specifically designed to prevent use of the disposal site by plants and/or animals (Lunz et al. 1978a). Most habitat development with dredged material has been unintentional, arising from placement of material in a location with nothing other than disposal in mind. Such disposal has created different kinds of habitats, ranging from aquatic to upland. For example, over 2,000 islands have been created with dredged material (Soots & Landis 1978). Purposeful habitat development has also occurred. For example, Garbisch (1977) identified 110 projects specifically designed to develop wetland habitat using dredged materials. Ten of these projects were on the west coast. Examples of intentional wetland and upland habitat development with dredged materials in and near the Pacific Northwest are Miller Sands in the lower Columbia River (Clairain et al. 1978) and Salt Pond #3 in south San Francisco Bay (Morris et al. 1978). Feasibility studies have also been conducted for salt marsh development in other Pacific Northwest locations, including areas of Grays Harbor, Washington (Armstrong et al. 1979; Vincent 1978).

Three main habitats can be created with dredged materials: aquatic, upland, or wetland. (The definitions of the major habitat categories used herein are those of Lunz et al. [1978].) Several specific types of each habitat can be produced and each targets different species or assemblages. Examples of general aquatic habitat development might include such projects as modifying substrate characteristics (e.g., particle size) to be more suitable to target organisms and the "sealing" of contaminated sediments by burial with clean dredged material (Lunz et al. 1978). New upland habitats are often created at the expense of underlying wetland or aquatic habitats. If certain critical upland habitats are lacking or marginal in quality in a particular area, this may be a positive trade-off. However, the profound reductions in the amount of wetland habitat throughout the world, which has corresponded to increases in human activity over the last century particularly (Albright et al. 1980), make it necessary to review very critically any habitat development which has as its consequence the loss of wetland areas.

Any of these major habitats might be the most appropriate for development under specific circumstances. Once the decision is made as to the type of habitat most appropriate, a key question to address is whether the newly developed habitat would be more valuable than the one it replaces. For example, salt marshes may be in short supply in an area, but their creation at

the expense of existing habitat would need to be assessed. Usually, the comparative values of habitats are not easy to determine and can be modified by several factors, such as the extent of similar habitats in surrounding areas and the abundance or lack of the target organisms chosen, including endangered species. It is generally believed that a diversity of habitat types in an area is more valuable to a greater number of species than is any one of the individual habitats covering the same area (MacArthur 1960; Abele 1974 in Lunz et al. 1978).

Physical & Biological Factors of Importance

Several physical and biological factors are important to the development of any of the major types of habitats. Physical factors may include: proximity to dredge sites; exposure to sun, wind, tide, and wave action; stability of foundation materials; elevation relative to tidal action; slope; substrate characteristics (texture, fertility, pH, contamination, etc.); necessity for stabilization; salinity (soil and water); climate and microclimate; availability and cost of plant species; timing of disposal (season and periodicity); and projected life of the designed habitat. Biological factors may include: existing biological communities and habitats smothered or impacted by dredged material disposal; proximity and extent of habitat similar to that altered by disposal; proximity and extent of habitat similar to that developed; projected use of the new habitat; the species selected as target organisms; population characteristics (ability to establish, compete, or reproduce); ability of plant species to stabilize substrate; etc. These physical and biological features, along with others, will determine the feasibility of a particular desired habitat development project. Several of these factors can be partially controlled by confining or stabilizing the dredged material. However, these actions can place further constraints on the design of the developed habitat, especially cost constraints.

CONCEPTUAL DESIGNS FOR HABITAT DEVELOPMENT AT JETTY ISLAND

Constraints

Several practical constraints affect potential habitat development concepts at Jetty Island.

- The location of the dredging sites (the turning basin in the Snohomish River channel, and downstream [Figure 1]) preclude consideration of the northernmost portions of the island as disposal sites (Malek pers. comm.).
- The southernmost area requires study of foundation stability before placement of significant amounts of the larger-grained dredged material can be considered.
- Confinement of the disposed material by means of a dike is counter to conditions set forth in the Consensus Guidelines, Future Development of the Port of Everett - Citizen's Planning/Mediation Committee (1977). The Consensus Guidelines specify that any allowed disposal "should be an extension in form and in character of the existing island."
- Economic considerations (as well as the Consensus Guidelines regarding confinement) de-emphasize investigation of extensive use of stabilization materials (rock debris, scrap tires, etc.) other than vegetation.
- The amount of new dredged material available for use is assumed to be 150,000 yd^3 initially, with subsequent maintenance dredging providing an additional 50,000 cubic yards/year average, dredged on a 2-3 year cycle (Malek pers. comm.).

Given the above constraints, the following concepts assume habitat development will take place in the mid-sections of the island (roughly within the area sampled by transect in this study), without confinement, for the most part without permanent stabilizing other than vegetation, and that 150,000 yd^3 of clean, fine sand dredged material will be initially available. Consideration of other physical and biological aspects will be addressed in the following paragraphs.

For the purpose of these conceptual designs, we assume no restrictions exist relative to minor restructuring or modification of existing upland areas of Jetty Island. Habitat loss by such activity will be weighed against new habitat gain,

just as for the loss of intertidal areas during dredged material disposal.

Habitats Most Appropriate for Development

Habitat Type and Location Selection

Habitat surveys of the Snohomish River estuary were most recently published in the Snohomish Estuary Wetlands Study (*SEWS*) Summary Volume by Shapiro & Associates (1978). (No more up-to-date breakdown on the areas of different habitats in the Snohomish River estuary is currently available.) Sand/mudflats (primarily off Jetty Island) covered over 3,000 acres (4.7 square miles), and eelgrass beds comprised over 40 percent (1,200+ acres) of that acreage. Salt marshes existed over only ~430 acres (~8 total acres occurred on Jetty Island in 1977, and ~10 acres occur there today) and swamp areas occurred over 1,650 acres. Vegetated uplands covered over 30,000 acres within the estuary, including most of the ~100 upland acres of Jetty Island.

It is not considered feasible to create strictly freshwater habitat, such as a pond or freshwater marsh, on Jetty Island. While the wildlife value and productivity of such habitats, especially in juxtaposition to saltwater areas, is recognized, several factors place constraints on their development. First, a constant freshwater source is not easily available. Second, the porosity and salinity of the soil on the island would necessitate lining the floor and walls of a freshwater habitat development site with impermeable material, such as clay or plastic. Third, berming to approximately +20 feet MHHW would be necessary to protect the freshwater environment from storms. This would require extensive modification of existing uplands, in addition to placement of newly dredged material. The costs and engineering associated with overcoming these problems would be prohibitive. Upland, salt marsh, and aquatic (sand/mudflat or eelgrass beds, etc.) habitats could feasibly be developed however.

Isolated upland habitat has value to the Snohomish River estuary in general. Jetty Island, in particular, provides upland areas isolated to some degree from predators and human influence; and as such, it is a valuable resource for several animal species, including breeding birds. Beach grassland is an upland type particularly appropriate for development on Jetty Island. As mentioned previously, beach grassland is presently limited in the Snohomish River estuary to the existing acreage on Jetty Island, so expansion of this acreage would benefit the wildlife species attracted by this habitat type. Furthermore, when newly created upland areas require stabilization against wind and wave induced erosion, the beach grassland community is best suited to the task.

Aquatic habitats surrounding Jetty Island, including eelgrass beds and unvegetated sand/mudflats, are extensive. Eelgrass beds are areas of high primary productivity (Albright et al. 1980), and provide important habitat for a variety of aquatic organisms, including several that are commercially important. Unvegetated mudflats, more often exposed than eelgrass beds at low tide, support large populations of invertebrates of lesser commercial or recreational importance (e.g., Callianassa and Abarenicola sp.) but are of great trophic importance to surrounding aquatic and terrestrial environments, primarily via the importance of these areas for feeding by fishes and shorebirds. Also, algal associations of very high primary productivity are often found in relation to mudflat areas, major genera being Ulva and Enteromorpha. While these aquatic habitats are important, they do not appear to be limiting in the Snohomish River estuary (~1,200 acres of eelgrass, ~1,800 acres of unvegetated mudflat) and therefore may not be the most appropriate habitats to develop through the use of dredged material.

Of the habitat types possible, beach grassland and salt marsh are by far the least abundant in the estuary. As mentioned earlier, beach grasslands are important to many species of wildlife and currently exist nowhere in the Snohomish River estuary other than on Jetty Island. Salt marsh is also not very abundant in the estuary. The proximity of extensive sand/mudflat feeding areas for shorebirds, which could be attracted by salt marsh habitat, helps make salt marsh establishment on the island an especially attractive prospect. In addition, salt marshes are important nursery grounds for juvenile salmonids, and decaying salt marsh vegetation is a source of seasonally large amounts of nutrients which are exported to surrounding aquatic habitats (Albright et al. 1980).

Salt marsh and beach grassland areas can easily be developed together as the major plant communities established on different elevations of dredged materials which have been placed and shaped so as to make the resulting formation especially suitable for these habitats.

Salt marsh development requires protected high intertidal areas which are essentially onshore. A likely location for creating such areas is around the narrow, south-central isthmus of the island. At that location, several designs, such as a spit extending north or south from the southern or northern bulges, respectively; a barrier berm enclosing the entire bay area formed by the isthmus; or chain islands in the same area, could create appropriate intertidal/shoreline areas for salt marsh establishment and allow for beach grassland development above MHHW. Such siting would eliminate some unvegetated sand/mudflat, but would minimize impacts to existing eelgrass beds and at the same time could have the added benefit of modifying erosion characteristics near the isthmus (see Tides, Currents, Waves and Storms) by "smoothing out" the shoreline contour. Also, the

maximum protected area could be created using the minimum amount of dredged material by working in this location.

Siting further to the north would entail the creation of an additional bulge in the shoreline and would produce additional areas where wave energy is directed sharply toward shore. Much further to the north is too far from the dredging site to be feasible. To the south of the proposed site, the stability of the existing substrate would require study before it could be considered as a development site. Also, the water in the extreme southern area is currently too deep to establish upland and marsh habitat with the proposed quantities of dredge material. That area is currently designated a disposal site of the Port of Everett, and the possibility of use restrictions cannot be determined at this time.

All of the habitat development concepts discussed in the following sections are based on habitat development in the general area of the isthmus.

Criteria for Habitat Development

Physical Criteria. Many physical factors will influence the success of any salt marsh establishment scheme and must be carefully evaluated and incorporated before the project begins. The factors listed below are considered critical by several authors (Kadlec and Wentz 1974; Garbisch 1977; Environmental Laboratory 1978; Woodhouse 1979).

a. Elevation. The elevation of the disposed dredge material must be monitored and controlled relative to tidal datums if the plant establishment project is to succeed. Too low an elevation will result in excessive tidal inundation, preventing the establishment or growth of the desired species. Too high an elevation may result in low groundwater levels and colonization by upland species. Williams and Harvey (1983), Woodhouse (1979), and Garbisch (1979) recommend observing nearby natural marshes to obtain the best estimates of suitable elevations for marsh establishment. Recent studies in the Northwest (Fonda and Disraeli 1979; McGee 1978) report elevational limits for all of the characteristic Puget Sound salt marsh species, including those already existing on Jetty Island. Table 7 lists these limiting elevations.

b. Slope. Because salt marsh vegetation is restricted to a small elevation range, slope is a critical factor in determining the extent of newly-created marshlands. To gain the greatest area, and still retain optimum plant growth, the slope should be nearly flat but still allow water to run off. If drainage is poor, pools of salt water may remain between tides, and plant growth may be stunted or inhibited in those areas (Woodhouse 1979). Garbisch (1977) cautions that sites developed by hydraulic dredge disposal will generally encounter material mounding at each outfall location, resulting in unacceptably steep slopes that will require grading.

Table 7. Recommended Plant Species for Habitat Development on Jetty Island

Habitat	SPECIES (REFERENCES)	SALINITY TOLERANCE	MOISTURE REQUIREMENTS	SOIL TYPE	WILDLIFE VALUE	SOIL STABILIZER	ELEVATION	PROPAGATION	DENSITY	MANAGEMENT TECHNIQUES
SALT MARSH	Lyngby's sedge (1,2,3,5)	fresh-brackish 0-20 ppt	wet-moist	silt-sand	cover, food	yes	9'-10' above MLLW	transplant April-June	0.5-1.0 meter on center	Responds to fertilization on sandy substrate; remove tidal debris
SALT MARSH	Pickleweed (2,3,5)	fresh-saline 0-35 ppt	wet-moist	sand	cover, food	yes	10'-12' above MLLW	transplant Feb-May	0.5-1.0 meter on center	Unreported
SALT MARSH	Seaside arrowgrass (3,5)	brackish-saline	wet-moist	mud-sand	food	yes	8'-10' above MLLW	transplant Feb-May	0.5-1.0 meter on center	Unreported; but may require debris removal
SALT MARSH	Three-square bulrush (3,5)	fresh-brackish	wet	sand	cover, food	yes	8'-9' above MLLW	transplant whole plants or tubers Feb-May	0.5-1.0 meter on center	Unreported; but may require debris removal; control wildlife grazing
SALT MARSH	Tufted hairgrass (1,2,5)	fresh-brackish	moist	silt-sand	cover, food	yes	10' above MLLW to EHW	transplant April-May	1.0 meter on center	Remove tidal debris; control wildlife grazing
BEACH GRASSLAND	Dune wildrye (4)	brackish-saline	moist-dry	sand	cover, nesting, food	yes	above MHHW	transplant Nov-Feb	0.5-1.0 meter on center	May respond to fertilization
BEACH GRASSLAND	Beach peavine (3,4)	brackish-saline	moist-dry	sand	cover, food	no	above MHHW	by seed, Feb-June	1.0 meter on center	

References:

(1) Knutson, P. L., & W. W. Woodhouse, Jr. 1983
(2) Environmental Laboratory 1978
(3) Landin, M. C. 1978
(4) Woodhouse, W. W. Jr. 1978
(5) McGee, Rebecca J. 1978

c. Salinity. Although free water salinity is often listed as a limiting factor in the growth of salt marsh species, soil salinities may be as, if not more, important (Penfound and Hathaway 1938). Furthermore, Barko et al. (1977) report that soil salinities may reach high levels in hydraulically deposited dredge spoils due to mixing of the sediments with saline water overlaying the deposits during the dredging operation. Subsequent drying of the deposited sediments can result in increased salinities. This phenomenon may occur at Jetty Island, as relatively high salinity values (27 ppt) have been recorded from the bottom of the channel in the area of the proposed dredging (Boule and Shea 1978). However, the final salinity of the newly deposited dredge spoils is dependent upon many factors, including elevation, freshwater input, and evapotraspiration (Purer 1942). Woodhouse (1979) reports that salinity levels in sandy materials are not likely to impede the establishment of locally adapted marsh species.

Kadlec and Wentz (1974) caution that many salt-tolerant species grow better in fresh or slightly brackish water, and salinities observed where the plants grow naturally are not necessarily the best criteria for determing whether the plant will grow at the new site. Nevertheless, the free-water and soil salinities recorded during this study and during recent studies in other Washington salt marshes (Fonda and Disraeli 1979; Northwest Environmental Consultants 1977) indicate that soil salinities should not be a limiting factor at Jetty Island.

d. Substrate. The sandy substrate that will be used to create new marsh and grassland at Jetty Island should not prevent the establishment of the recommended species, but post-planting fertilization may be required to achieve desired growth rates. Woodhouse (1979) reports that planting is easiest on sandy soils, but the principal disadvantage of this type of soil is a typically low nutrient content. He further notes that this problem is often ameliorated by nutrient-rich estuarine waters, but in some cases fertilization may be required to assure rapid establishment. Harvey (1983) also indicated that, in general, fine sands with some silt or clay fraction provided the best substrate for plant growth because of the high ion exchange capacity and consequently high nutrient availability. Garbisch (1977) states that fertilization should be conducted for all marsh establishment work in sandy sediments. Whether fertilization will be required at Jetty Island can probably best be determined by performing a nutrient analysis of the dredged material at the time the plan is implemented.

e. Exposure to Wave Action. Marsh plants are generally able to tolerate low or moderate wave energies but cannot withstand high wave energies (Woodhouse 1979). While many factors determine wave regime and affect the feasibility of a marsh establishment plan, Woodhouse suggests that fetch is probably the most readily determined and most meaningful factor, and sites with fetches of greater than 4-5 miles are unsuitable. A marsh establishment project at Rennie Island, Washington, was

abandoned primarily due to unresolvable problems associated with high wave energy at the site (Vincent 1978).

f. Exposure to Debris. Burial of marsh vegetation by washed-up logs, eelgrass detritus, and inorganic debris may impede or prevent marsh plant establishment. If marsh establishment is attempted in the litter deposition zone, Garbisch (1977) recommends planting the most mature stock available to increase its chances of survival. He reports, however, that the zone of litter deposition is an excellent location to construct tidal creeks in marsh establishment schemes. These creeks will increase water circulation, increase habitat diversity, function as depositories for litter, and provide the optimum environment for the decomposition of the litter and export of nutrients.

Biological Criteria. All species considered for the vegetation establishment scheme should be native both to Western Washington and to the plant community that is being established. Restricting the selections with these two basic criteria will prevent the introduction of species that may be potential pests, ensure the selection of species that will successfully compete within the community, and provide resident wildlife with appropriate habitat components.

Hunt et al. (1978) recommend selecting the species for a particular site after considering:

- basic growth requirements;
- tolerances to extremes of temperature, light, moisture, pH, salinity, contaminants, and nutrients;
- growth form;
- reproductive methods;
- production of wildlife food and cover;
- competitive ability;
- ability to modify site conditions;
- hardiness;
- resistance to disease and insects; and
- need for maintenance, management, or control.

Once species are selected with these criteria, their arrangement within the marsh will be dictated primarily by their salinity tolerance and tolerance to tidal inundation.

Existing vegetation patterns near the site should be observed to determine the appropriate species composition for

each plant community. Additionally, recent literature describing salt marsh zonation, community structure, and species composition should be consulted.

Recommended Habitats

After consideration of the physical and biological factors influencing Jetty Island, two distinct plant communities, beach grassland and salt marsh, are recommended for establishment. The beach grassland will stabilize the substrate in the uplands (above approximately +12-1/2 feet MLLW) on the western shore of the newly deposited dredge spoils, where high wave energy and litter accumulation prevent the establishment of salt marsh. In protected areas, a salt marsh community is recommended for the zone between +8 and +12 feet above MLLW.

The following discussion describes the species that are recommended. The pertinent characteristics of each species were also summarized in Table 7.

All of the species are native to Western Washington and presently occur in the Snohomish River estuary. Consequently, they are adapted to local environmental conditions and are available as a seed source or for transplanting to the new site.

The information in the following discussion and Table 7 is based on the reports of many workers, including Kadlec and Wentz (1974), Environmental Laboratory (1978), Woodhouse (1979), Landin (1978), McGee (1978), Northwest Environmental Consultants (1977), Fonda and Disraeli (1979), Jefferson (1975), Clairain et al. (1978), and Knutson & Woodhouse (1983).

Low Marsh Vegetation. Between approximately +8 and +10 feet, existing low marsh vegetation on Jetty Island is composed of Lyngby's sedge, pickleweed, seaside arrowgrass, and three-square bulrush. These species, subject to the guidelines discussed below and summarized in Table 7, are recommended for establishment at the same elevations. Several additional species, including Jaumea, Lilaeopsis, ditchgrass, low clubrush, and seaside plantain are also present in this zone in minor amounts and can be expected to establish at the new site through natural invasion.

Lyngby's sedge is an excellent soil stabilizer, easily transplanted, and tolerant of the soil and free-water salinities expected at the new site. It grows at most elevations throughout a marsh but typically creates dense stands only in the lowest vegetated zones. Natural establishment occurs from seeding and stranded pieces of rootstock; artificial establishment is best accomplished by transplanting. Lyngby's sedge provides food for birds and mammals and nesting cover for ducks and geese.

Pickleweed is found at all elevations in Washington salt marshes. It characteristically colonizes and stabilizes the lowest elevations on sandy substrate and also forms dense mats in

highly saline high marsh zones. Pickleweed is easily transplanted, although several authors recommend against it, noting that it rapidly invades disturbed areas if a propagule source is nearby. Pickleweed provides food and cover for small mammals and food for ducks.

Seaside arrowgrass is another common mudflat pioneer in Washington salt marshes, occurring from +6 feet MLLW up to the upper limit of the marsh. An excellent soil stabilizer, this species characteristically forms large circular colonies on bare mudflat that effectively trap sediments. Seaside arrowgrass has been successfully propagated by transplanting and seeding. It provides food and cover for waterfowl.

Three-square bulrush occurs in brackish marshes throughout Western Washington, colonizing mudflats and providing excellent food for waterfowl, particularly geese. It is not as salt-tolerant as pickleweed or seaside arrowgrass. In the Nooksack River delta, three-square bulrush occurs in a zone extending from +7.5-10 feet MLLW , although it provides most of its cover below +9 feet. Above 9 feet, it is replaced by Lyngby's sedge. Three-square bulrush has been propagated by transplanting tubers or entire plants.

High Marsh Vegetation. Pickleweed and tufted hairgrass are the species recommended for establishing a high marsh zone on Jetty Island. Both species are good soil stabilizers, and are otherwise appropriate in consideration of the physical and biological factors discussed previously.

Pickleweed was previously discussed under "Low Marsh Vegetation".

Tufted hairgrass, lacking on Jetty Island but reported elsewhere in the Snohomish River delta, is an excellent choice for planting above MHHW at the new site. It is easily propagated by transplanting, a good soil stabilizer and sediment accumulator, and provides good cover and fair food value for wildlife.

Beach Grassland. Dune wildrye is the recommended species for establishing new beach grassland habitat and stabilizing newly created beach areas in areas above +12 feet MLLW on Jetty Island.

Dune wildrye is an excellent soil stabilizer, capable of rapid growth, and provides forage and cover for many wildlife species. However, there is very little information available on the propagation and management of this species. European beachgrass, a non-native species that is easily propagated, has been the preferred species for west coast dune stablization projects since the 1930s. Nevertheless, Dune wildrye has been successfully established along the Oregon coast, and the experience gained there makes it a good choice for establishment on Jetty Island. Temperature and timing are critical

considerations for the successful transplanting of this species; temperature must be below 13° C, and transplanting must be done during the plant's dormant period, November through February.

If increased species diversity is desired at the time of establishment, beach peavine and silver bursage could be intermixed with the wildrye planting. However, these species already exist in Jetty Island's beach grassland community and probably will naturally establish themselves at the new site.

Wildlife Species Benefited

The development of beach grassland and salt marsh habitats would benefit a wide assemblage of vertebrate and invertebrate species by providing additional habitat diversity in the estuary. As previously mentioned, beach grassland and salt marsh habitats are among the most limited habitats presently occurring in the estuary. The addition of beach grass and salt marsh acreage is expected to complement wildlife use of those habitats now present on and immediately adjacent to Jetty Island.

For example, shorebirds now feeding on the mudflats and narrow sandy beaches of Jetty Island are likely to utilize salt marsh habitat for additional feeding as well as for resting and protection from wind. Because of the open, exposed nature of the west side of Jetty Island, very little protection from wind and waves is now provided.

The addition of beach grassland would provide acreage above and beyond that now present on Jetty Island, thereby most likely providing additional habitat for the following mammals: deer mice (Peromyscus maniculatus), Townsend's vole (Microtus townsendii), and shrews (Sorex spp.). Hawks, short-eared owls, and other raptorial birds would benefit from any additions to prey populations.

Until covered by beach grass and other vegetation, dredged material is expected to provide potential nesting sites for colonial nesting birds, such as Arctic terns, glacous-winged and western gulls, and Killdeer.

The addition of salt marsh habitat and associated sloughs and open sand or mudflats would benefit a wide assemblage of organisms. Invertebrate populations, particularly Corophium amphipods, Neomysis, Harpacticoid copepods and insects, will provide a food base for fish species, such as chinook and chum salmon, smelts, and shiner perch. Congleton and Smith (1976) found that juvenile chum and chinook salmon utilize Skagit River marshes and tidal flats for feeding on dipteran adults and larvae, harpacticoid copepods, and the estuarine amphipod Anisogrammus confervicolus. Fresh et al. (1978) determined that coho salmon sampled with beach seines at the Nisqually delta ingested high numbers of gammarid amphipods, cumaceans, isopods, and mysids.

Judging from the results of beach seining conducted at Jetty Island by Jones & Stokes Associates biologists, marsh areas open to tidal influence could also be expected to support other juvenile fish species, such as shiner perch, surf smelt, and Pacific herring. Pearcy and Myers (1974) found the Yaquina Bay estuary in Oregon to be an important spawning and rearing area for approximately 45 non-salmonid fish species.

Salt marsh will also provide habitat for higher trophic organisms, such as waterfowl, rails, song sparrows, and a variety of raptors. A protected marsh area will provide refuge for shorebirds and waterfowl. Wading birds, such as the great blue heron, will be benefited as well. Table 6 provides a list of avifauna and mammalian species likely to utilize salt marsh habitat.

Concepts for Salt Marsh Development

Salt marshes could be established in a variety of ways near the central portion of Jetty Island. Suitably protected areas could be created behind dredged material placed in any of several configurations on the unvegetated mudflats west of the existing isthmus. Designs, such as an enclosed pond, a protected lagoon, or semi-protected shorelines of elevations appropriate to salt marsh development, could result from such dredged material disposal. Once a protected areas is created, salt marsh could initially be developed along the protected shoreline fringe at the proper elevations. Dredged material made available by later maintenance dredging of the lower Snohomish River channel (2-3 years later) could raise the remaining enclosed or protected area, and an extensive salt marsh could be developed. Alternatively, some of the existing upland area of the isthmus could be used to fill the protected area so that the maximum amount of salt marsh could be developed in the beginning, eliminating the need to rely on future disposals to complete the design. This would be desirable from the standpoint of minimizing damage and disruption to an established fringe marsh by later disposals and activity.

Relatively protected areas could also be produced in the lee of a chain of small islands of dredged material, with more islands, or fill between islands and joining them, being placed by subsequent maintenance dredging operations (eventually forming lagoons or enclosed ponds, and more marsh area, successionally).

Several concepts for potential salt marsh development are discussed in detail in following sections.

Enclosed Pond Concept (Design No. 1)

A continuous spit, attached at both ends to Jetty Island (Figure 5), would create an enclosed pond. A surrounding fringe of elevations appropriate to salt marsh would exist. If the floor of the pond were filled to the elevations appropriate for

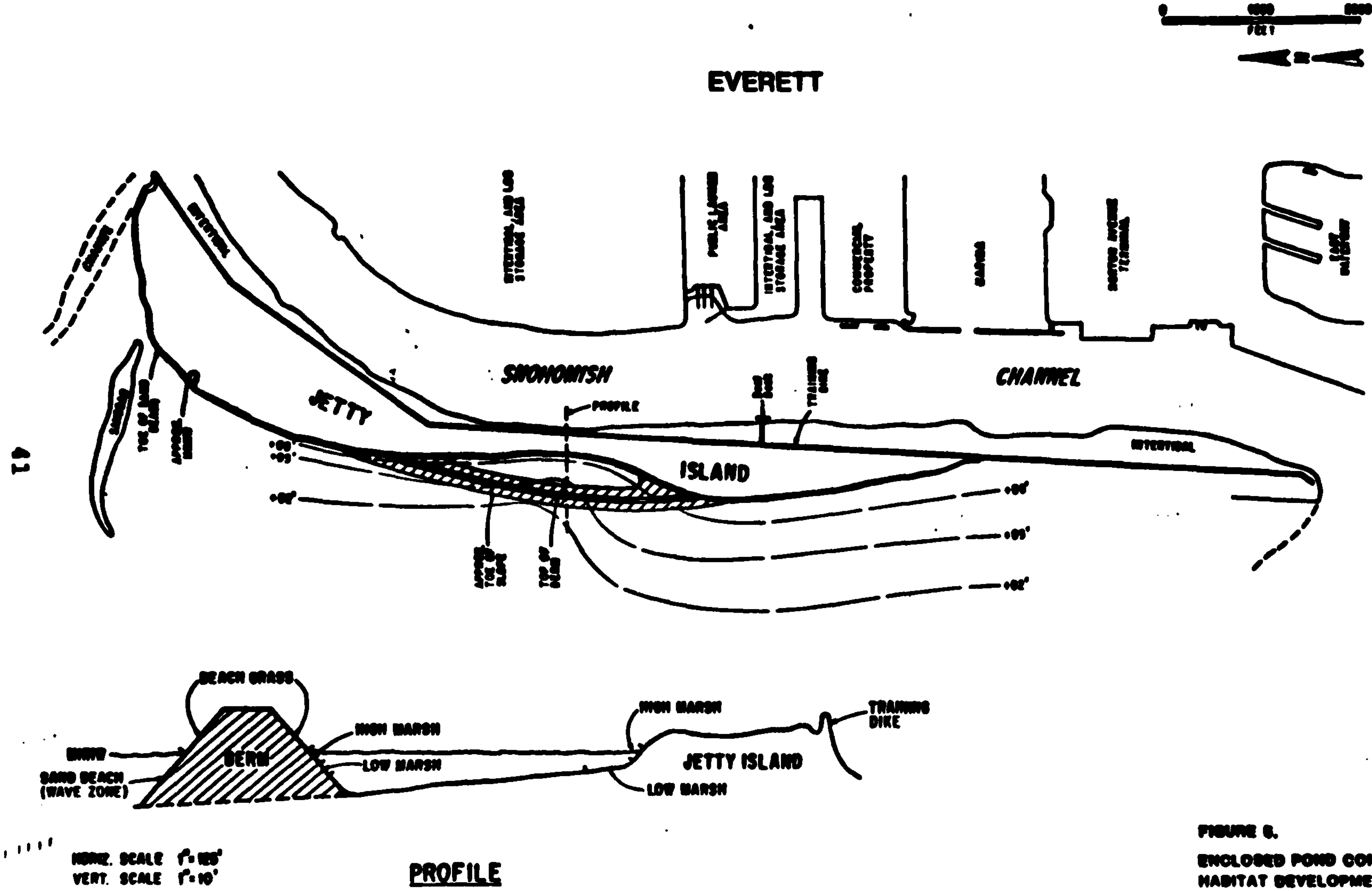


FIGURE 8.
ENCLOSED POND CONCEPT FOR HABITAT DEVELOPMENT AT JETTY ISLAND, EVERETT, WA

salt marsh vegetation (+8-10 feet MLLW), a much greater area of marsh could be developed than if habitat development was limited to construction only of a protective berm.

An area of about 15 acres (to the existing shoreline) would be enclosed by a 150,000 yd^3 (dry volume) berm of the following average dimensions: 3,000 feet in length, 10 foot height, top width 35 feet, side slopes 1:10, top elevation +15 feet MLLW. Table 8 presents a summary of design features for this alternative. The berm would cover approximately 15 acres of tide flats. About 5 acres of shoreline ringing the enclosed pond created by this berm would be at elevations between +8 and +12 feet MLLW and therefore appropriate for salt marsh establishment. Approximately 8 acres above +12-1/2 feet MLLW could be established as beach grassland. The floor of the enclosed pond would be at a minimum elevation of +6 feet MLLW. If the floor area were raised to an average elevation of +8 feet MLLW, ~50,000 yd^3 of additional fill would be required. This could come from subsequent maintenance dredging operations or from existing upland areas of the island, which average +13.6 feet MLLW elevation. Approximately 5.5 acres of isthmus upland, leveled to +8 feet MLLW, would provide the required fill, while adding to the area available for salt marsh establishment (then totalling 19 acres). The area in such a pond in which salt marsh vegetation would actually thrive would likely be much less than the area available, due to the lack of periodic inundation which is necessary to maintain this habitat.

The amount of intertidal sand/mudflat habitat removed by this design would be approximately 30 acres; however, 3 acres would be added by this new shoreline. Shoreline lost would roughly be replaced by the new outer shoreline of the berm. Existing upland habitat loss would be negligible if no existing land were used as fill behind the berm, and in fact, 8 upland acres would have been created. If 5.5 acres of existing upland were used as fill, there would be a net increase of 3 acres in upland habitat.

An enclosed pond design would have the physical advantage of being more resistant to wave and tide erosion than would designs involving spits with openings for tidal inundation on the west side of the island. However, the species benefits would be somewhat different. Wildlife use (i.e., by birds and small mammals) would be similar to other designs; but since no direct water access to the bay would exist, the marsh would not be useful to fishes (e.g., juvenile salmonids) for feeding and refuge. (See Table 9 for a discription of the benefits to fish and wildlife resulting from this design.) Also, the surrounding aquatic areas would not directly benefit by increased nutrient inputs from decaying marsh vegetation. Since most water would only enter an enclosed pond during storms with high waves, and via rainfall, it is possible that an enclosed pond could act as a salt sink. If this happened, salinities could quickly increase beyond the tolerance limits (see Table 7) of many of the targeted marsh vegetation. Also, since tidal fluctuations would be

Table 8. Summary of Design Features for Habitat Development

CONCEPT/DESIGN	TOTAL ACREAGE	BERM DIMENSIONS	CUBIC YARDS OF FILL (IN THOUSANDS)	HABITAT (acres) BEACH GRASSLAND	MUDFLAT/ SANDY BEACH	POND	LOW MARSH +8-10' MLLW	HIGH MARSH +10-12' MLLW	REMARKS
Enclosed Pond Concept									
• Design No. 1 w/o Upland Alteration (w/Upland Modification)	30 (34)	3,000' x 35' x 10'	150 (210)[a]	6(6)	4(3)	15 (-)	2(20)	3(5)	Design resistant to erosion; possible problem of salt buildup; no tidal connection
Open Lagoon Concept									
• Design No. 2A w/o Upland Alteration (w/Upland Modification)	34 (41-44)	3,000' x 35' x 10'	150 (210-240)	8(8)	21(7)	-	2 (17-21)	3(8)	Potential erosion at tip - need for stabilization; tidal connection on north
• Design No. 2B w/o Upland Alteration (w/Upland Modification)	30 (36)	2,500' x 35' x 11'	150 (210)	5(5)	20(5)	-	2(16)[b]	3(8)[b]	Less erosion problem than 2A but stabilization necessary; shorter spit and in deeper location
Enclosed Lagoon Concept									
• Design No. 3A (w/Upland Modification)	(35)	3,000' x 35' x 11'	210 (150+ upland)	(6)	(5)	-	(19)	(5)	Design resistant to erosion; tidal connection through training dike; 5 acres of existing uplands converted to marsh
• Design No. 3B w/o Upland Modification	30	3,000' x 35' x 11'	150	5	20[c]	-	2[c]	3c	Design resistant to erosion; subsequent filling needed from other dredge operations; culvert to east side would provide tidal inflow
• Design No. 3C w/o Upland Modification	30	3,250' x 35' x 10'	150 1st yr 83 3rd yr	8	12	-	3	7	Subsequent filling needed for cross berm; stabilization of end of spit necessary; box culvert for tidal influence
Chain Island Concept									
• Design No. 4 w/o Upland Modification	±30	Islands	<150	UK	UK	-	UK	UK	Judged not feasible because of stability & wave erosion problems; stabilization required

a 150,000 cu yds from dredging, 60,000 cu yds from adjacent uplands.
b If dredged material wer- added later in lieu of altering uplands, only 19 total acres of marsh would be created.
c An additional 10 acres o. marsh habitat could be created if dredged material was added in subsequent years.
UK - Unknown

Table 9. Benefits to Fish and and Wildlife from Habitat Development

CONCEPT/DESIGN	FISH	WATERFOWL	SHOREBIRDS	RAPTORS	TERRESTRIAL MAMMALS	MARINE MAMMALS
Enclosed Pond Concept						
● #1 w/o Upland Modification (w/Upland Modification)	-(-)	+(*)	+(*)	*(*)	+(*)	-(-)
Open Lagoon Concept						
● #2A w/o Upland Modification (w/Upland Modification)	+(+)	*(+)	+(+)	*(*)	+(*)	UK
● #2B w/o Upland Modification (w/Upland Modification)	+(+)	+(+)	+(+)	*(*)	+(*)	UK
Enclosed Lagoon Concept						
● #3A (w/Upland Modification)	(+)	(●)	(+)	(*)	(*)	-(-)
● #3B w/o Upland Modification	+	●	+	*	*	-(-)
● #3C w/o Upland Modification	+	+	*	*	*	UK
Chain Island Concept						
● #4 w/o Upland Modification	●	●	+	*	*	UK

KEY:

- None * Minor + Moderate ● Significant UK Unknown

virtually eliminated in such a pond, salt marsh could exist at best as a very narrow fringe.

Open Lagoon Concept (Design Nos. 2A & 2B)

A lagoon, as described herein, is not necessarily an area permanently covered by water but one which receives tidal exchange, or is inundated, on essentially a daily basis. Several lagoon designs could be formed in the central area of Jetty Island.

An easily constructed lagoon would entail creating a spit or spits to enclose a bay formed at the isthmus of the island. One spit extending north from the southern bulge or south from above the isthmus area would create a large protected lagoon within which salt marsh could be established. Variations on this design would be to create two shorter spits with an opening in the middle, or one spit not connected to the island itself (i.e., with openings at the northern and southern ends).

Those channel areas would allow inundation on high tides and provide access for fishes, including juvenile salmonids, which could feed on insects and other invertebrates in the salt marsh. They would also provide conduits for nutrient export to surrounding aquatic habitats. However, any gap on the bay side would be especially subject to erosion from of tides and waves. It is beyond the scope of this report to predict the ultimate fate of sediments as a result of erosion in these circumstances, but it is very probable that without stabilization, at least at the ends of the spits, the configurations discussed would not remain as originally placed, and the life span of the established habitats could not be forecast with certainty. Some form of artificial (non-vegetative) stabilization could remedy this problem. Such stabilization would be required at any gaps placed in the protective spit (i.e., around the intertidal tip of the spit itself and over the floor of the gap). Due to the high costs of potential stabilizing materials (riprap, old tires, etc.), only designs which include a single gap will be considered.

Design 2A - Straight Spit/Open Lagoon. The average dimensions of a straight spit with one gap (Figure 6) created from 150,000 yd^3 (dry volume) of dredged material would be the same as given for Design No. 1. Such a spit would protect an area of approximately 19 acres (to the existing shoreline) and would have approximately 5 acres of internal shoreline, between +8 and +12 feet MLLW, appropriate for salt marsh establishment (Table 8). Eight acres appropriate for beach grassland would be created. The floor of the enclosed area would average about +5 to +6 feet MLLW. If the lagoon area were filled to a minimum +8 foot elevation, either with new dredged material from subsequent maintenance dredging or by use of some of the existing upland material of Jetty Island, nearly the entire 19 protected acres could be established as salt marsh. The amount of fill material

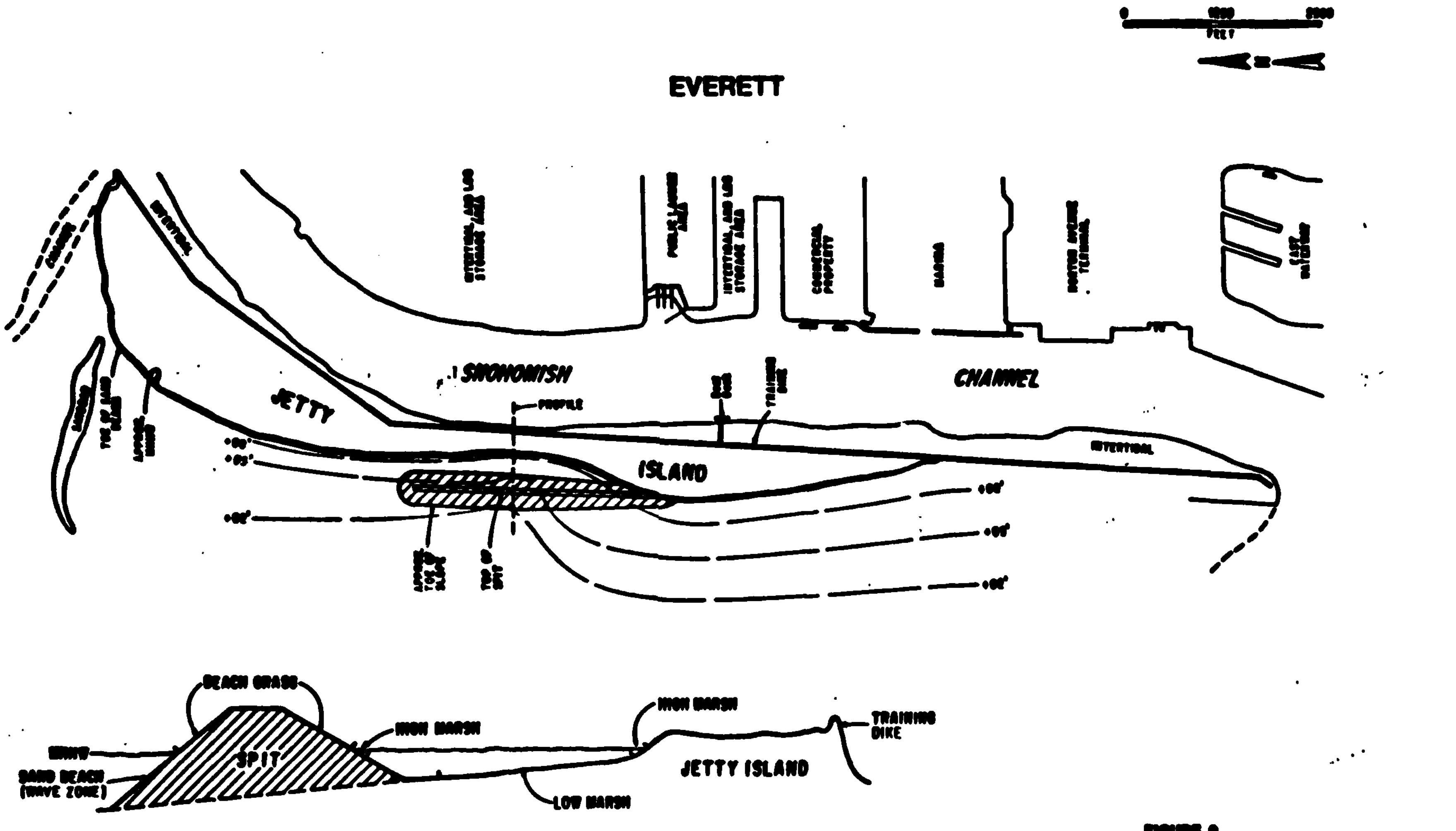


FIGURE 8.

STRAIGHT SPIT DESIGN, LAGOON CONCEPT FOR HABITAT DEVELOPMENT AT JETTY ISLAND, EVERETT, WA

required to raise the elevation of the lagoon floor to a minimum +8 feet MLLW would be ~60,000-90,000 yd^3. An area of 6.5-10 acres of the existing upland isthmus area of Jetty Island, if lowered to +8 feet MLLW, would provide this volume of fill. In this manner, 25-30 acres could be created having elevations appropriate for a salt marsh .

The straight protective spit would cover about 15 acres of existing sand/mudflat habitat. However, over a mile of new shoreline would be created by this design. If 6.5-10 acres of existing isthmus upland were lowered and used as fill behind the spit for salt marsh elevation establishment, actual upland acreage loss would range from zero to a maximum of 4 acres. Table 9 depicts the fish and wildlife benefits associated with this design.

Design 2B - Bowed Spit/Open Lagoon. A straight spit might be more subject to wave action than would some other shape, such as a bowed spit (Figure 7) which should break up wave energy and direct it more longshore to the north and south. Such a bowed spit would be shorter, due to its being placed over an area with a greater average depth. The dimensions would be approximately: 2,500 feet in length, 11 foot average height, top width 35 feet, side slopes 1:10, top elevation +15 feet MLLW. About 19 acres would still be protected by the bowed spit, and ~5 internal shoreline acres would be at elevations appropriate for salt marsh development. In this case, 6 acres of new upland could be developed as beach grassland (Table 8). As for the straight spit, filling the protected lagoon would allow nearly all of the enclosed 19 acres to be established as salt marsh, and if the fill material came from the existing isthmus, ~25 acres of salt marsh would be possible.

The bowed spit would cover 11 acres of existing sand/mudflat. However, about one mile of new shoreline would be created; and as with the straight spit, upland acreage (5 acres) would be gained. If existing isthmus acreage were used as fill, approximately 1 acre of uplands would be lost. See Table 9 for an accounting of the benefits to fish and wildlife associated with this design.

Enclosed Lagoon Concept (Design Nos. 3A &3B)

Design 3A - Enclosed Lagoon, Filled From Uplands. A combination of Designs 1 and 2 would be a fully-enclosed lagoon marsh. Creation of this design would entail, first, completely enclosing the bay area with a berm connected at both ends to the island as discussed under Design #1 above, creating a pond area, and 8 new upland acres for beach grassland. The upland area of the isthmus would be lowered to a minimum +8 feet MLLW east to west across the entire island and the resulting material used to fill the pond to a minimum +8 feet MLLW, creating 24 acres having elevations appropriate for salt marsh and yielding no overall loss of upland acreage. By opening small gaps in the very top of the training dike (to the +8 feet MLLW level), this area would

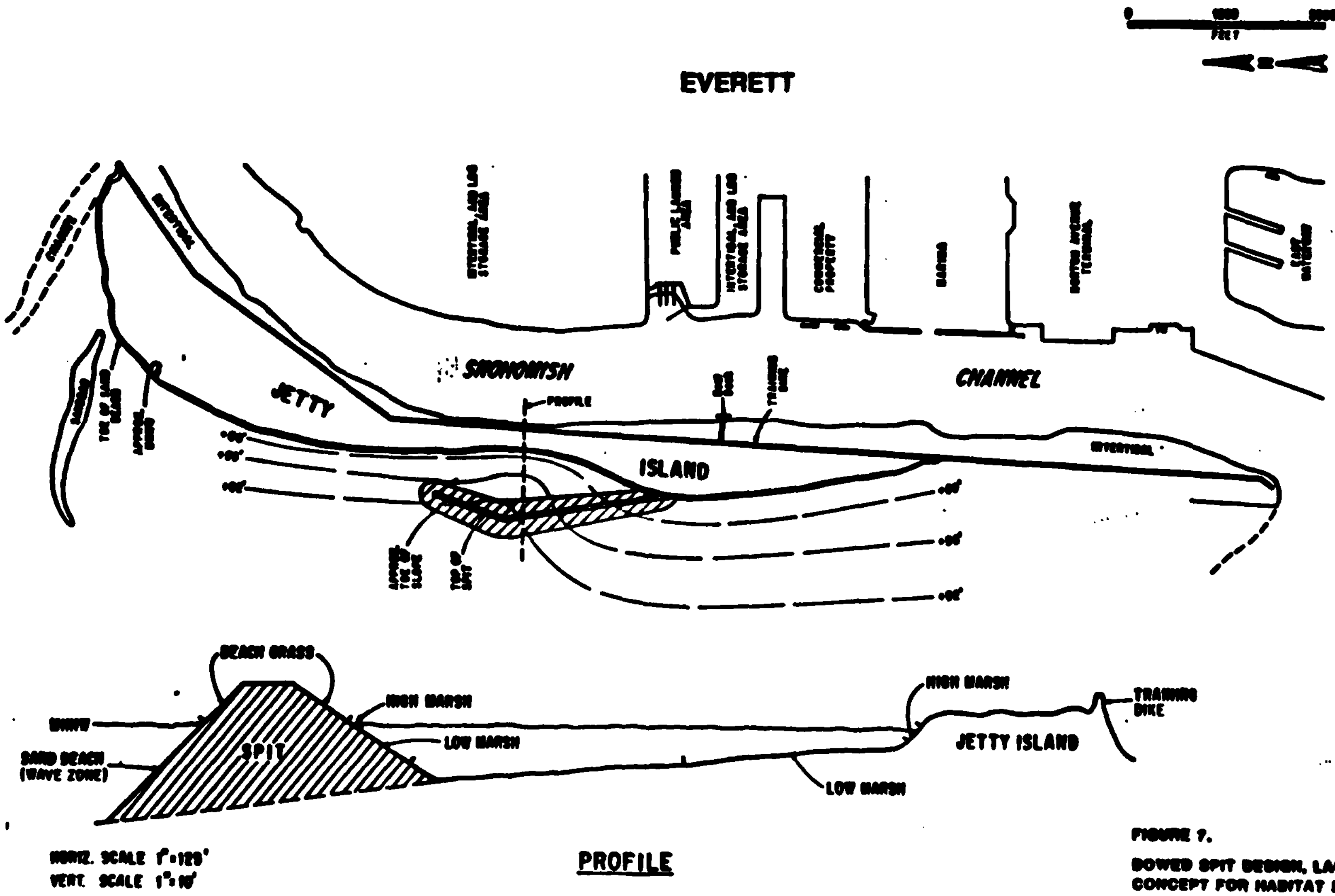


FIGURE 7.

BOWED SPIT DESIGN, LAGOON CONCEPT FOR HABITAT DEVELOPMENT AT JETTY ISLAND, EVERETT, WA

receive regular tidal inundation, resulting in a lagoon rather than a pond (Figure 8). There are several advantages to this design. First, a lagoon and marsh habitat would be created, allowing use by fishes and nutrient exchange to surrounding aquatic habitats. Second, the size of the marsh would be maximized from the outset, eliminating the need for subsequent dredged material disposal to complete the design. Therefore, no damage to any initially established fringe marsh would occur by later dredged material disposal and activity. Also, the design is protected from erosive wave forces. Finally, no artificial stabilization would be required. Thus, both the life of the design and the species benefits would be maximized and development costs kept low.

This design would be practical, however, only in conjunction with some modification of existing upland areas. Without such modification, water from any developed salt marsh could not be exchanged from the protected river side of Jetty Island, and an enclosed lagoon as described would not be possible.

Design 3B - Enclosed Lagoon, Without Fill From Uplands. If only minimal modification of existing uplands were allowed, an alternative design would entail the placement of a culvert(s) or unlined channel(s), with a minimum elevation of +8 feet MLLW, across the isthmus area (Figure 9). In this way, very little upland area would be disturbed and water access would still be from the eastern side of the island (thus avoiding potential erosional problems). Only a fringe of marsh within the lagoon could initially be established, and completion of the design (establishment of marsh over virtually the entire 15 acres protected by the spit) would require the use of additional new dredged material 2-3 years later (see Table 8). Thus, the potential would exist for damaging the previously established fringe of marsh during subsequent project development. However, balanced against this would be the expected increased life of the marsh area due to better protection by the enclosing berm (i.e., there would be a greater certainty relative to predicting the final outcome of the project than would exist for less protected marsh designs). Fish and wildlife values of this alternative are shown in Table 9.

Design 3C - Enclosed Lagoon/Open Lagoon. One possible variation to the enclosed lagoon concept would be a combination open lagoon and enclosed lagoon in which a second berm would be joined from the bowed spit to Jetty Island (Figure 10). Box culverts could be placed in the berm to provide tidal influence to the enclosed lagoon. No alteration to the Jetty Island uplands would be necessary since tidal action would be provided through the box culverts. Such a design would require an additional berm 750 feet in length and containing approximately 38,000 cubic yards of dredged material. That additional fill material would need to be derived from a later dredging cycle since construction of the main spit would require all material from the initial dredging operation (Table 8).

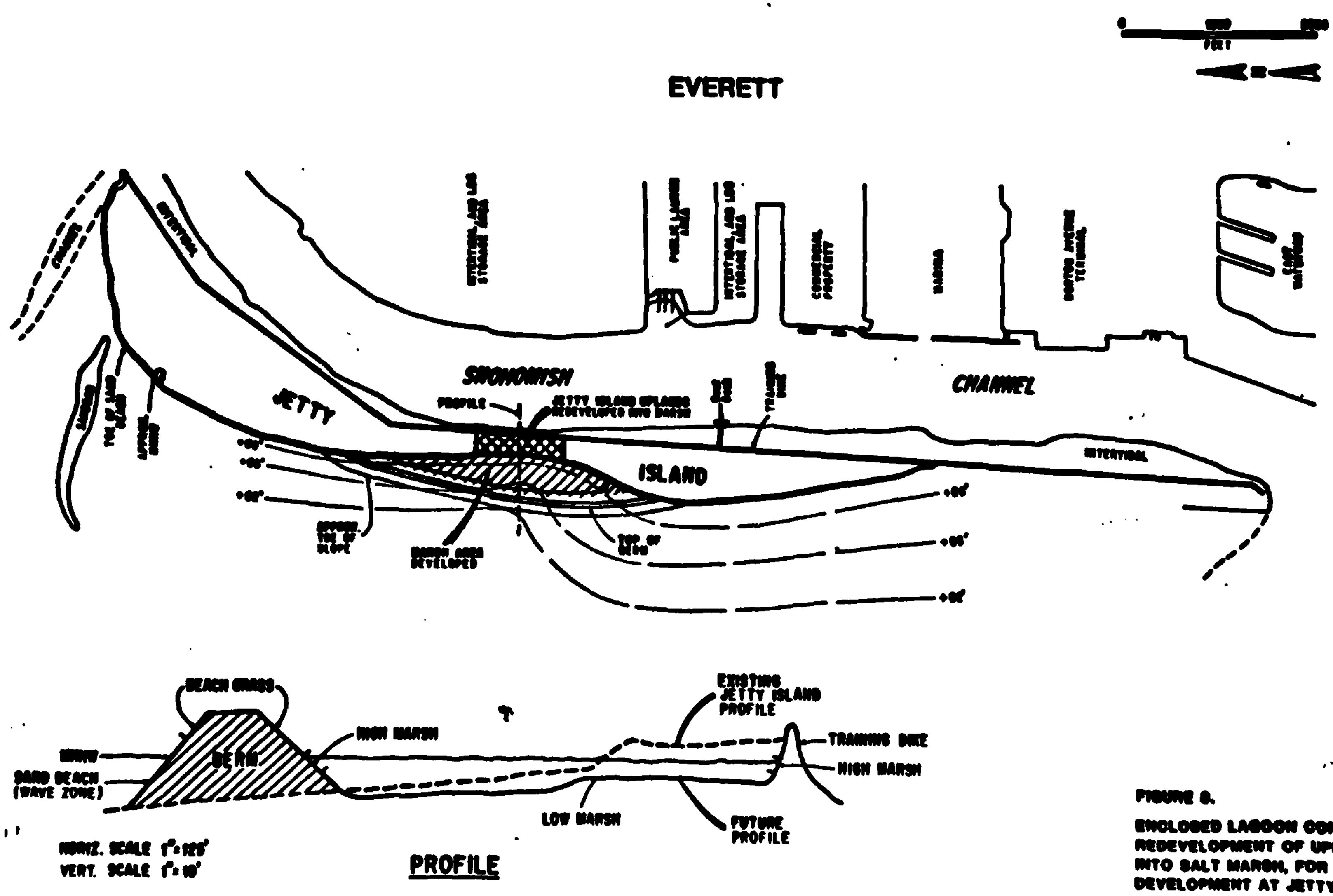


FIGURE 8.

ENCLOSED LAGOON CONCEPT, WITH REDEVELOPMENT OF UPLAND AREA INTO SALT MARSH, FOR HABITAT DEVELOPMENT AT JETTY ISLAND, EVERETT, WA

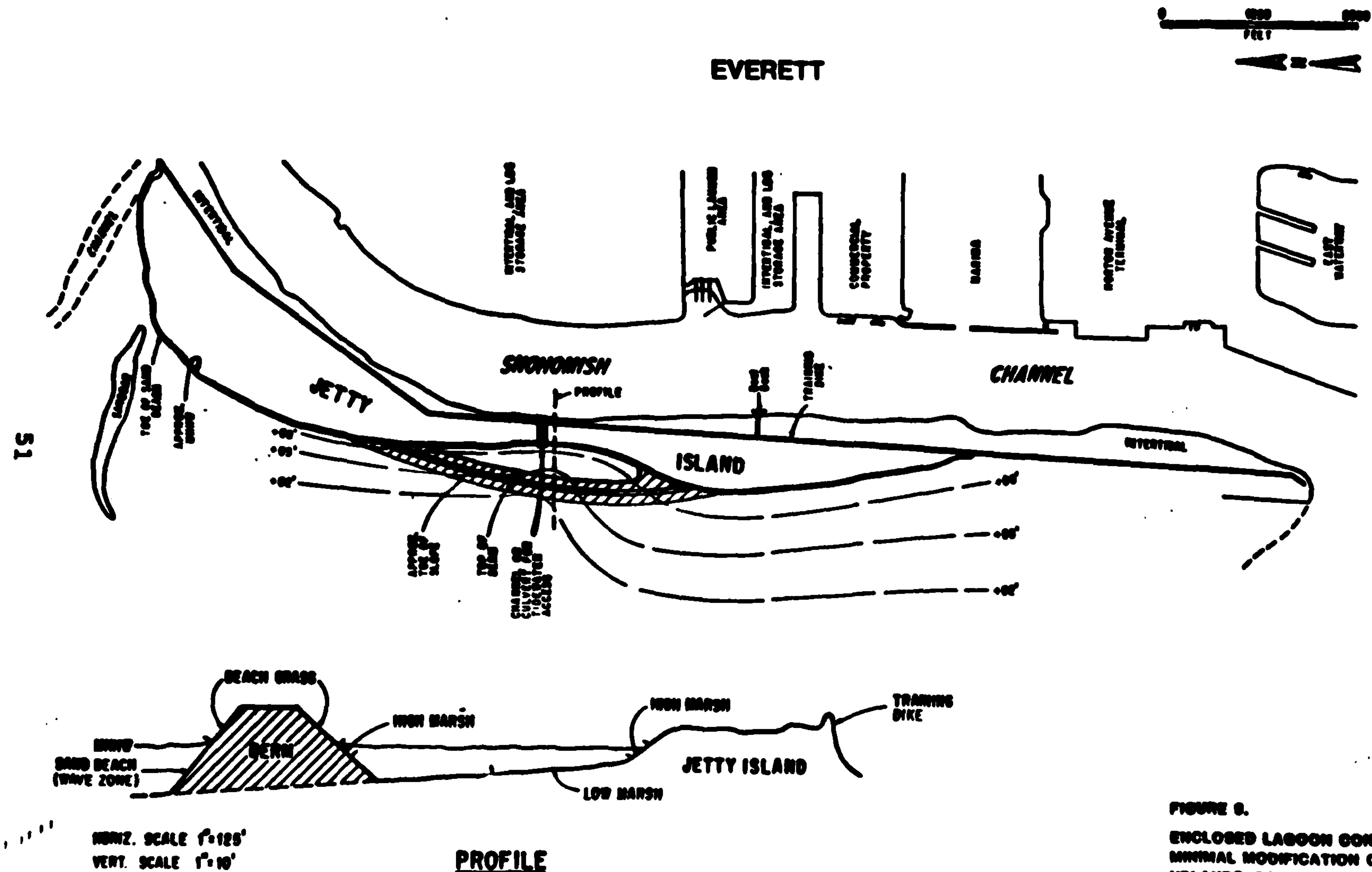


FIGURE 6.

ENCLOSED LAGOON CONCEPT, WITH MINIMAL MODIFICATION OF THE UPLANDS, FOR HABITAT DEVELOPMENT AT JETTY ISLAND, EVERETT, WA

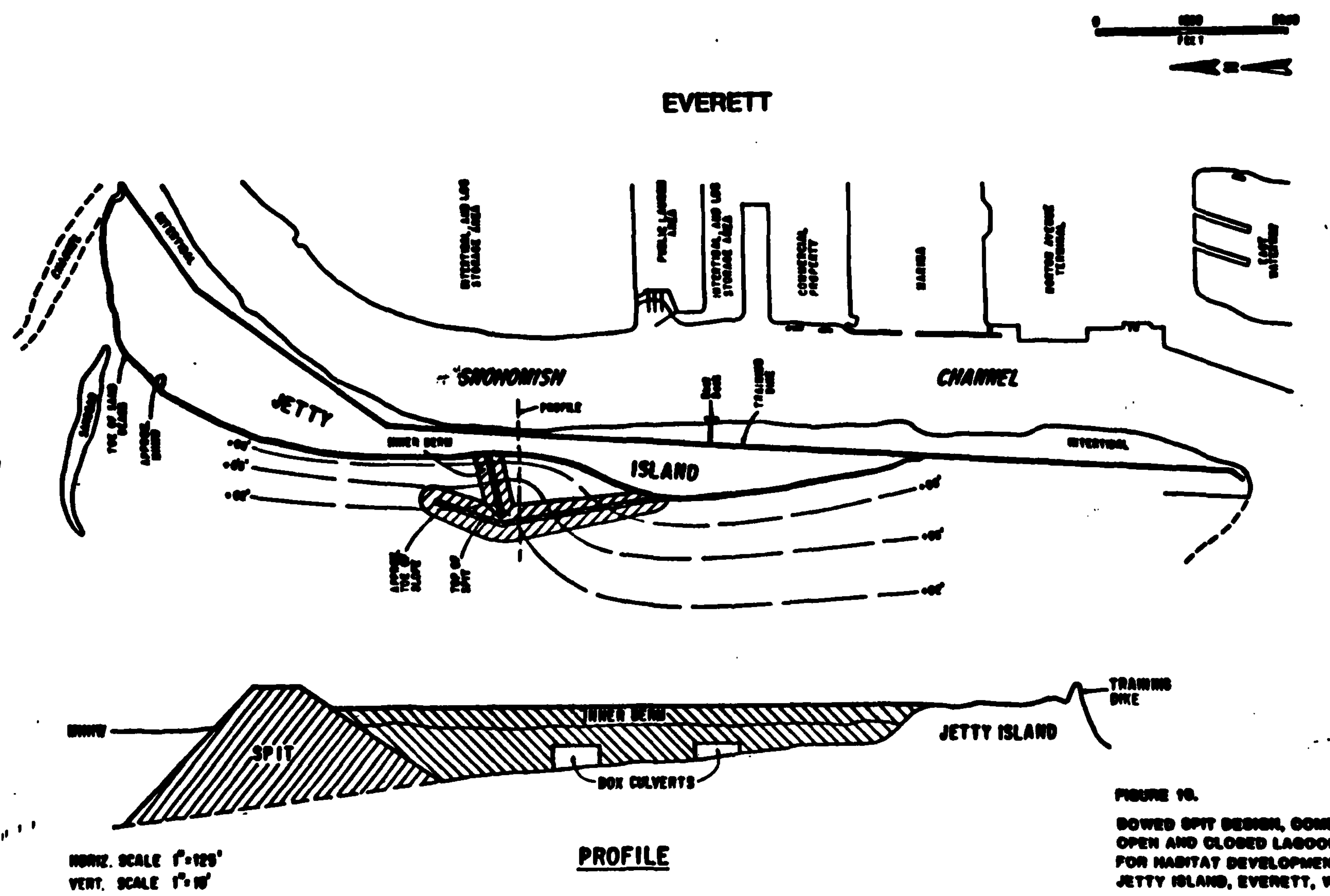


FIGURE 10.

BOWED SPIT DESIGN, COMBINATION OPEN AND CLOSED LAGOON CONCEPT FOR HABITAT DEVELOPMENT AT JETTY ISLAND, EVERETT, WA

The advantage of this design would be that the inner berm would be protected from wave action by the bowed spit and greater diversity of habitats could be achieved because of the added protection afforded to the enclosed lagoon. The inner berm would create additional beachgrass habitat that would otherwise be salt marsh or unvegetated sand flats.

The maintenance and proper operation of a box culvert within the spoil materials could initially be a problem until vegetation has stabilized the berm and settlement and erosion have been checked. A second disadvantage would be that some disturbance to established marsh and beachgrass habitat would be necessary during construction of the inner berm and culverts. Fish and wildlife values of this design are shown in Table 9.

Chain Island Concept (Design No. 4)

A chain of islands could be placed along the same general area as a berm or spit (Figures 5-10), providing a relatively protected lagoon-like area around which salt marsh could be established. Substantially less dredged material than needed for other designs would initially be required to create these islands. The area available for salt marsh development would initially be less than with other designs, since only the most leeward portions of each island would be sufficiently protected. Since the existing isthmus shoreline area would also not be as well protected as with other designs, the extent of marsh development is expected to be somewhat less there as well. A maximum number of marsh acres could not be developed until several years (dredging cycles) later, when subsequent dredging could fill the inter-island areas and create a spit or berm. Then, an entire protected or enclosed area with the correct elevations, as defined in the first three concepts, could be developed.

The practicality of chain islands is much reduced by their susceptibility to wave erosion. Since the shoreline-area-to-volume ratio would be much less than for a spit or berm, and since many local areas of concentrated wave energy would likely be created, it is judged that development of chain islands would not be feasible off central Jetty Island without substantial artificial stabilization. The high cost of such stabilization would probably require that some other design be considered first.

The main advantages of creating a chain of islands with dredged material are that isolated areas of different habitats (e.g., which might be attractive to birds for breeding, etc.) could be created, and the volume of material required would be less than for other designs. The isolation of the islands would not be substantial because the entire area would be exposed at low tide, and therefore such areas would probably not be more attractive to breeding birds or other wildlife than are other areas of Jetty Island (which is already isolated from man and many potential predators). The major reason for the development

of chain islands would be that not enough material existed to create one of the other designs. All the concepts discussed in this report assume that 150,000 yd^3 of dredged material would be available at the start of project development. Since the other designs discussed could be created with this amount of material, development of chain islands is not considered to be most appropriate for Jetty Island.

PREFERRED PLANS

Accepting that salt marsh and beach grassland establishment would be the most beneficial and appropriate habitat development plan for Jetty Island, only those designs which have the highest probability of actually allowing healthy salt marsh to establish can be given serious consideration. For this reason alone, both Design No. 4, chain island concept (due especially to major uncertainty over whether substrate materials would remain where placed), and Design No. 1, enclosed pond concept (due to lack of tidal exchange and potential salinity problems), were not considered feasible (Table 8).

A heavily weighted factor in determining specific preferred plans must be the area of the target habitats which could be developed under different designs. The various potential open lagoon (Design No. 2) and enclosed lagoon (Design No. 3) concepts could each initially develop a moderate amount of salt marsh if no existing upland areas were modified to complete the final target designs, and an additional 5-6 acres of beach grassland could be established. A more extensive marsh area could be created if some upland areas could be modified, and overall upland habitat loss would be minimal. The open lagoon design created from a straight spit, and with the protected area filled from existing isthmus material, has the potential for allowing development of the greatest absolute area as salt marsh (up to 30 acres) (Table 8). Following this in potential area for salt marsh development is the open lagoon created from the bowed spit (~25 acres), then the enclosed lagoon, Design 3A (20+ acres). All these designs allow 5-6 acres of new beach grassland development as well.

The projected life span of each design must also be taken into account. Only speculations could be made in this report based on the very scant information presently available on waves, currents, storms, and foundation stability of the area. From a qualitative standpoint, open lagoon designs created from a spit with a gap are expected to have a shorter life, and to protect the enclosed marsh area less well, than would a solid berm. Artificial stabilization would increase the expected life of a spit to an unknown extent. However, the same amount of stabilization applied to a continuous berm would be expected to increase its effective life even further.

Configuration (shape) will also affect the expected life of any design. A bowed barrier spit, generally smoothing the contours of the island could, if properly designed, enhance the stability of the shoreline of the entire island. A straight barrier spit would be less likely to eliminate or reduce areas of concentrated wave energy or may possibly cause even more concentrated energy to be directed at itself. A continuous

curving berm should act much like a bowed spit smoothing out the island contour and averaging wave energy along the entire shoreline, as opposed to concentrating it in any one area. The bowed spit and continuous berm designs would, therefore, be expected to have longer effective lives.

Taken together, it would appear that the most desirable design would be an enclosed lagoon (Design No. 3A), developed at one time by grading a portion of the isthmus uplands, establishing salt marsh over the entire area, and with tidal access from the protected east side. A relatively large area (approximately 20 acres) of salt marsh could thus be developed, being as well protected and having as long an expected life as possible, and with potential fish and wildlife benefits as great as for any other design (Table 9). Also, the maximum new area of beach grassland (6 acres) is possible with this plan (Table 8).

Ranked second would be an enclosed lagoon (Design 3B) with only a fringe marsh initially developed (i.e., without lowering isthmus uplands for use as fill). This design would allow for minimal modification on the existing uplands, as tidal access would be from the protected east side of the island via a culvert or channel. This design would incorporate the most stable protection for the developing marsh, while still allowing for maximum potential fish and wildlife species benefits; and subsequent maintenance dredging would produce a final design different from the most preferred plan only in total potential marsh acreage (15 vs 20 acres) (Table 8).

The third of the preferred plans is the open lagoon (Design No. 2B) created by a bowed spit. This is considered to be the best option if no uplands modification can be undertaken. A fringe marsh, and then an area marsh created from subsequent dredge disposal, could eventually cover as much as 19 acres (Table 8). (The 25 acre area mentioned earlier as possible with this design could not be realized without modification of the uplands.) However, this assumes no erosional problems, and the final area of stable marsh could be less. If artificial stabilization were used, a greater final area of stable marsh should exist. An area of beach grassland slightly less than for the other preferred designs, but still significant (5 acres), could be created with this design. Because of erosion and cost uncertainities, the bowed spit/open lagoon concept is recommended last.

The last of the preferred plans would be the Enclosed Lagoon/Open Lagoon (Design 3C) created by adding a cross berm between the bowed spit and Jetty Island. This option would provide more diverse habitat because of the open and closed lagoons. Water transfer would occur through a box culvert installed in the berm. No modification of upland areas would be necessary. Potential erosion problems would be similar to those mentioned for Design No. 2. Marsh habitat created would be approximately 10 acres, and approximately 8 acres of beach grassland would occur (Table 8).

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APPENDIX

Jetty Island Field Sampling Notes, September 6-7, 1983

9/6/83 - Water Quality

All measurements were made with an Horiba, Model U-7, Water Quality Checker calibrated just prior to use. Salinities were calculated from standard curves of conductivity and temperature.

Snohomish River Channel (Mid-Channel)
(See Figure 3 for locations)

3:20 - 3:40 PM. Tide flooding near high, good current to N.
Water sampled @ 2' below surface

LOCATION	TURB. (NTU)	COND. (mmho/cm)	(SAL.) (ppt)	D.O. (mg/L)	TEMP. (°C)	pH
1	01	32.0	22.8	10.7	14.6	8.0
2	02	31.7	22.7	8.8	14.5	8.0
3	01	32.4	23.0	8.8	14.8	8.1

Bay Side of Island (See Figure 3)

4:30 PM. Water sampled ~50' offshore, 2' below surface
(Tide high @ 5:45 PM).

At Seine Station 4	01	26.4	19.3	9.4	15.4	8.0
(at bottom = 2-1/2:		26.7	19.4)			

9/7/83 - Water Quality

Snohomish River Channel (Mid-Channel)
(See Figure 3 - same locations as 9/6/83 sampling, + gap)

Tide low, beginning to flood; but net current down-channel.

LOCATION	TURB. (NTU)	COND. (mmho/cm)	(SAL.) (ppt)	D.O. (mg/L)	TEMP. (°C)	pH
(12:55 - 1:10)						
1	03	0.9	0.7	9.2	14.5	7.5
2	03	0.5	0.4	11.0	14.7	7.6
3	03	0.6	0.5	9.1	15.0	7.4
(1:25) At gap, N end of island, on rock dike ~8' offshore	04	0.7	0.6	9.3	14.9	7.3

Bay Side, Tide Low @ 11:28 AM.

LOCATION	TURB. (NTU)	COND. (mmho/cm)	(SAL.) (ppt)	D.O. (mg/L)	TEMP. (°C)	pH
11:30 ~Site A2 (4" Deep channel on flats. Slow current to S)	03	24.2	17.0	8.7	17.9	7.8
12:10 ~100' W of D3 (Slow current to N. Offshore, ~6" deep)	05	26.5	18.4	10.5	17.9	8.2

Tides 9/6/83: Tide Low (-1.6) at 10:43 AM
Tide High (11.9) at 5:45 PM

9/7/83: Tide Low (-1.1) at 11:28 AM
Tide High (12.0) at 6:17 PM

Jetty Island Intertidal Benthic Sampling. September 6, 1983

Southern transects (C&D) were sampled first, with the lowest stations (C3 & D3) being established and sampled at as close to low tide as possible. Site stakes were set, and a 1 m^2 quadrat placed with its eastern corner at the site stake. Quadrats were photographed and generally characterized, and burrows were censused over the entire 1 m^2. At each site, 1/4 m^2 was excavated to ~20 cm and seived through a 5 mm mesh screen. Organisms retained were preserved in 70 percent ETOH. Also, a 1L core was taken from each site (to 10 cm depth, with a 7.8 cm diameter core, taken twice). 1L core samples were screened with a 1 mm seive, and retained organisms were preserved in 70 percent ETOH. All collected organisms were returned to the laboratory for identification.

For transects A & C, the western 1/4 m^2 was excavated, and the 1L core sample came from the eastern 1/4 m^2. Transects B & D had the northern 1/4 m^2 excavated, and the 1L core samples also came from the same northern 1/4 m^2. Numbers of organisms found per site as reported in Table 4 have been normalized, so that they are directly comparable.

See map for locations of transects.

<u>Transect: A</u>

Head stake in scotch broom, in an area of erosion N. of isthmus and N. of turn in Jetty (which occurs @ B.M. "A"). Heading: 295°.

<u>Site A1</u>: (12:15-12:30)
400' from head stake
Substrate: Sand
Site on a "reef" (Parks 1973) (<u>not</u> on very top)
Burrows: S = 14 W = 21 N&E not counted
Core and excavation done. No <u>Abarenciola</u> burrows.
No plants or algae.

<u>Site A2</u>: (12:00-12:15)
660' from A1 (1,060' from head stake).
At landward edge of lower elev. area (beside 4" deep x ~50' wide channel in flats).
Substrate: Sand/silt
Burrows: S = 18 E = 21 W = 19
N = 20 + 2 sprigs <u>Zostera</u> (sm. blade)
No <u>Abarenicola</u> burrows

Site A3: 570' from A2 (1,630' from head stake).
(11:35-12:00) Still in lower elev. area, but elev. rises to the W., and flats at this tide level extend far to the W. Sparse *Zostera* cover (intermediate blade size between other low elev. *Z. marina* and higher, sm. blade *Zostera*).
Burrows: N = 21 W = 19 E = 14
S = 15 + 3 *Zostera* sprigs
Substrate: Sandy silt
No *Abarenicola* burrows
Cored and excavated

Observations Along Transect A:

Zostera beds may curve to the W. (or end) with elevation change (shallower, overall, toward N. end of island). "A" doesn't slope off steadily as do other transects; i.e., salinity may not be reason for end of *Zostera* bed.

Transect: B Head stake 350' N of N end of scotch broom patch (which is in area of erosion) at N end of isthmus.
Heading: 295°

Site B1: 175' from head stake.
(12:35) Substrate: not characterized
Burrows: 59 + 2 *Abarenciola* casts (overall m^2)
Trace of *Ulva*
Core and excavation in N 1/4 m^2

Site B2: 250' from B1 (425' from head stake).
(12:00) Substrate: not characterized
Burrows: 52 (overall m^2) (no *Abarenicola* burrows)
Trace of *Ulva*, trace of *Zostera* (sm. blade sp.?) (new growth)
Core and excavation in N 1/4 m^2

Site B3: 250' from B2 (675' from head stake).
(11:30) Substrate: not characterized
Burrows: 33 (overall m^2) (no *Abarenicola* burrows)
Trace of *Ulva*
Nephtys sp., no *Zostera*
Core and excavation in N 1/4 m^2

Transect: C

Head stake at S end of narrow isthmus.
Heading: 316°

<u>Site C1</u>: (10:00-10:15)	490' from head stake. Substrate = sand Quadrat eastern corner at stake Narrow blade *Zostera* cover over entire quad. Burrows by 1/4 m^2: N = 21 E = 14 W = 16 S = 13 (+138 *Zostra* sprigs) No *Abarenicola* burrows obvious W 1/4 m^2 excavated Core sample lost. Re-cored 9-7, 12:00 (E corner)
<u>Site C2</u>: (9:30-9:55)	465' from C1 (955' from head stake). Substrate = silt/sand 20% *Ulva*/*Entero*. cover, E corner Pic. #15, = 1st taken on JI's roll today. Burrows by 1/4 m^2: N = 27 S = 31 W = 36 E = 21 (under algae) No *Abarenicola* burrows evident W 1/4 m^2 escavated. E corner core taken (Scattered *Z. marina* beds begin ~75 paces W from C2)
<u>Site C3</u>: (10:20-10:45)	355' from C2 (1,310' from head stake). Substrate = sandy silt w/clay globs 45 *Z. marina* sprigs in overall quad Burrows: S+E = 12 N = 23 W = 13 No *Abarenicola* burrows

<u>Observations Along "C"</u>:

- Dungeness crab molts in *Zostera*
- Scattered cockles (*Clinocardium*)
- EVV & GR noted many *Paranemertes* at C1 (and generally in higher intertidal elev.'s of Jetty Island's bay side)
- None of Parks' (1973) "reefs" until Transect "B"
- An animal (large bivalve?) "squirted" at us (like a geoduck does) on 9-6 <u>and</u> 9-7, ~10" W of C2. It was not collected.

<u>Transect: D</u>

Head stake at S "point" (W end of southern bulge in island, S of isthmus).
Heading: 300°

<u>Site D1</u>: (1:05)	365' from head stake. Substrate: not characterized Burrows: 67 (overall m^2) No *Abarenicola* burrows Core <u>and</u> excavation in N 1/4 m^2

Site D2: (~9:30)
290' from D1 (655' from head stake).
Substrate: not characterized
Burrows: 92 (overall m^2)
+1 *Abarenicola* burrow
Trace *Enteromorpha*, trace *Ulva*
Core and excavation in N 1/4 m^2
(Deeper digging showed primarily *Callianassa* & *Cryptomya*)

Site D3: (9:55)
~450' from D2 (1,105' from head stake).
(just above tide line at this time)
Substrate: not characterized
Burrows: 6 (overall m^2)
Scattered *Z. marina*, 5% *Ulva* cover
3 Opisthobranch egg cases (sac-like) in mud, covered w/grains
Core and excavation in N 1/4 m^2
(Deeper digging = primarily *Callianassa* & *Cryptomya*, & 1 *Callianassa* molt)

Jetty Island Sampling Beach Seining, September 6, 1983

(Tide High @ 5:45 PM)
(See map for locations)
The seine was 100' long x 3' high, having 1/4" mesh.

Seine 1: ~50' S of navigation tower at N end of isthmus (S. of Transect "B"),
5:20 PM. Set was right on shore (0-20' out) due to steep drop-off.
Closed to S.
Catch: 18 shiner perch (*Cymatogaster aggregata*) (~50-70 mm)
1 staghorn sculpin (*Leptocottus armatus*)

Seine 2: At head stake of Transect "C".
5:05 PM. Set to ~100' offshore, ~3' depth.
Closed to S.
Catch: 13 shiner perch (*C. aggregata*) (~60-70 mm)
7 juvenile herring (*Clupea harangus*) (~70-80 mm)
4 juvenile surf smelt (*Hypomesus pretiosus*) (~80-100 mm)
1 staghorn sculpin (*L. armatus*)
1 chinook salmon smolt (*Oncorhynchus tshawytscha*) (~100 mm)
several transparent larval/juvenile surf smelt (*H. pretiosus*) (~30-50 mm)

Seine 3: At head stake of Transect "D".
4:45 PM. Set to ~100' offshore, ~3' depth.
Closed to S.
Catch: 11 shiner perch (*C. aggregata*) (~60-70 mm)
1 staghorn sculpin (*L. armatus*)

Seine 4: At end of path from boat dock, ~200' S of Transect "D". 4:30 PM. Set to ~50-75' offshore, ~3' depth. Closed to N.
Catch: 2 shiner perch (*C. aggregata*) (~60-70 mm)

Groundwater Salinity

Two groundwater samples were taken September 7, 1983. Both were taken at low tide from vegetated intertidal areas on the east side of the island, near the southern end (Figure 3). Sample 1 was taken in a Lyngby's sedge patch; Sample 2 in a seaside arrowgrass patch. A hole was dug in the middle of each patch down to the root zone (~10-15 cm), and the groundwater that percolated into the hole was collected. Solids were allowed to settle for 7 days, and the salinity of the water was measured with an Horiba, Model U-7, Water Quality Checker.

Groundwater Salinity (ppt):

Sample 1: 17.1
Sample 2: 14.5

Vegetation Notes

An informal botanical survey of Jetty Island was performed September 7, 1983. The primary purpose of the visit was to ground truth the aerial photo interpretations, but some qualitative notes were recorded concerning species in flower, distribution, density, and vegetation profiles from mudflat to uplands on the east and west sides of the island. Comparative observations were made to determine the accuracy of the descriptions recorded by Phillips (1977), Parks (1973), and Burrell's (1978) mapping.

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